MI Note #0258
Single Turn Extraction Design for NuMI

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This note outlines two options for single turn extraction to the NuMI target and describes the most straightforward option in enough detail for implementation. I also investigate an alternate extraction orbit into the transport line by reducing the roll angles of the extraction Lambertsons and c-magnet.

The original design for NuMI extraction, as described in TM-1946 (NuMI note NuMI-B-92), was to use fast resonant extraction with an electrostatic septa located between quad 601 and 602 and the Lambertsons located at quad 608. This provided for about 270 degree phase advance between the septa and Lambertson. The septa was located upstream of Q602 so that (it was felt) the quad could shield the RF cavities from losses. However, the beta at the entrance to the septa is too small (~30 meters) and losses are unacceptably large. Concerns about activation of the RF instrumentation and cavities as well as ground water activation have led to a decision of implementing a single turn extraction system capable of extracting a full turn (i.e rise time < 1.6 μs and flattop of 10.6 μs)

Since the extraction Lambertsons are located around quad 608 in the Main Injector, there are two potential locations where extraction kickers might be located. The first is just downstream of Q606 which is ~80° in phase from the Lambertsons and the second option is just downstream of Q602 which is ~260° in phase from the Lambertsons. Neither location is advantageous in terms of phase advance. The peak beta function at the center of the quads ranges between 55 to 58 meters. The kickers would be located several meters downstream of the quad and would have an average beta of around 40 meters. The entrance to the first Lambertson is located about 3.5 meters upstream of Quad 608. The horizontal beta function is again around 42 meters, rising to 58 meters at the center of the quad. The horizontal dispersion through this region is zero.

Kicker strength

The full width (+/- 2.45 σ) of a beam with a 95% normalized emittance of 40 π-mm-mr at the entrance to the first Lambertson is

$$W = \pm 2.45\ \mathrm{sqrt}(\varepsilon\ \beta/6(\gamma\beta))$$
$$= \pm 2.45\ (1.5)$$
$$\cong \pm 3.6\ \mathrm{mm}.$$

To get an estimate of the minimum required kicker strength, we choose to keep the edge of the 95% beam envelope at least 4 σ from the edge of the Lambertson steel at all times. The Lambertson septa is 4 mm thick, so the minimum centroid separation at the entrance would be ~ 23 mm.

Using nominal lattice functions at the kicker and Lambertson locations, the strength required to produce this separation of 23 mm at the entrance to the first Lambertson, LAM60A which is just upstream of Q608, is

$$\theta_{kick} = \Delta x \ / \ (\beta_{kick}\, \beta_{lam})^{1/2} \sin\psi_{k\text{-}l}$$

$$\cong 5\ 60 \text{ urad}$$

where β_{kick}, β_{lam} are ~40 and ~42 meters and $\sin\psi_{k\text{-}l}$ is ~ 0.98. At 120 GeV/c this corresponds to a minimum integrated strength of 2.24 kG-m (0.573 kG/magnet). This corresponds to about 77% of the nominal strength of the MI-52 multimode kicker and 120% of a (modified) Recycler kicker. Both of these systems use two magnets in series.

Kicker choices

We can minimize or eliminate engineering effort if we agree to only consider *existing* kicker magnet and power supply designs. Currently, the **Recycler kickers (at nominal 54 kV on PFN) do not meet the minimum integrated strength requirements.** The MI-52 multi-mode kickers (at nominal 54 kV on PFN) exceed the requirements. The MI-52 kicker strength is not strong enough, however, to use only a single magnet by increasing the PFN voltage. Both of these systems have a +/-1% flatness specification.

Another kicker magnet option might be to use existing abort kicker magnets. These magnets are 1.89 meters long with a field of 0.67 kG/magnet with rise times of ~ 1 usec. However, its flatness is more on the order of +/-5%. An initial investigation shows that the horizontal movement on the target baffle to be ~ +/-1 mm due to a 5% error in the minimum kick angle above. The movement in the large vertical bend string is on the order of +/- 4 -5 mm. This could be a problem for 40 π beam where this motion coupled with the beam size would use up 35 mm out of the 46 mm physical aperture leaving only +/-5 mm If this is acceptable, it could be an option to building new extraction kickers. This needs further discussion.

Based upon the required strength and desire to not undertake a major engineering effort, it is proposed to use a duplicate of the MI-52 kicker system. If, the Pulse Forming Network (PFN) of the existing MI-52 kicker will never be used again (no full turn extraction to the Tevatron, Pbar or Switchyard) the MI-52 PFN could be used. However, if there is a potential for full turn extraction in the future, it would need to be duplicated.

Kicker locations

The location at Q606 is attractive since it does not put a 15 mm orbit distortion of the extracted beam through the RF cavity region. However, there only 3.259 meters (128.3 inches) between the downstream end of Q606 *steel* and the upstream flange of a MI RF cavity. Additionally, this space is currently occupied by the 2nd Harmonic cavity to be used in coalescing. In order to fit a kicker in this location, the 2nd Harmonic cavity would have to be moved and space would need to be reserved for bpm, valve, and connections to the cavity. This would leave on the order of 2.4 meters for the kicker magnet and spools. This is about half of a MI-52 kicker system and would require a magnet capable of a field of 1.14 kG. **It is clear that, without major engineering effort, a single magnet would not be an option and the location at Q606 should not be considered.**

Therefore, the optimal location for the NuMI extraction kicker is downstream of Q602. This space is currently occupied by the horizontal Schottky detector and transverse wide band detector. These devices would have to be moved to the upstream side of Q602 between the damper detector and kicker. Currently there is a 5-foot spool between the horizontal damper pick-up and kicker just upstream of Q602. This is not enough space to place both the horizontal Schottky detector and transverse wide band detector. I would propose placing the Schottky detector between the damper and kicker and placing the transverse wide band detector upstream of the kicker. In addition, the pinger and DCCT would need to be shifted downstream or moved to another location. If the pinger were relocated the DCCT could remain in its current location. The lattice and Table 2 show the pinger being relocated to ss601 (just to show that it fits.) The current pinger has both horizontal and vertical turns and has a rise time of ~20-30 μsec. We would like to replace the current pinger with two magnets (that could be placed adjacent to quads) having a rise time of less than a turn (10.6 μsec). The replacement could be timed to be coincident with the installation of the kickers so we could remove the existing pinger and free up the needed space for kicker installation.

Space requirements and straight section layout

Each kicker magnet is 77 inches long with a 5-inch end pack and an 8-inch spool piece between the kickers. This gives an insert length of 182 inches. This should be placed as close to the quad to produce the largest kick possible. The current placement in the MAD file has the upstream flange exactly 20 inches downstream the quad 602 steel. This should be enough room for the position detector (to remain) between the quad and kicker. Currently a beam valve is located downstream of Q601 so one is not needed here. Table 1 shows the current positions, lattice functions, and physical aperture of the devices in the straight section 601 and 602. Cross section diagrams of these devices, obtained from Jim Crisp, are included in the back of this report. Table 2 shows the proposed positions and lattice functions of the devices. Devices listed with a * will be new or moved. Cross-section drawings for the various devices are included at the end.

Table 1. Straight section 601-602 Current Layout

	Position	Length	Beta x	Beta y	Aperture
Quad 601	0		9.87	61.95	
VDPU	2.4	0.51435	11.98	52.53	3.998" diameter
spool	3.93		14.33	45.52	6" diameter
VDK	5.16	1.22555	16.63	40.33	3.959" diameter
spool	5.29		16.91	39.79	6" diameter
GRIFFEN	6.82	1.53035	20.31	33.91	5.77" diameter

spool	6.93		20.62	33.49	6" diameter
WBPU (LLRF stipline)	8.52	1.59004	24.84	28.06	4.72" plate diam.
spool w/ion pump	12.14		36.72	18.10	6" diameter
*HDK	13.36	1.22555	41.47	15.49	3.959" diameter
spool	14.90		47.91	12.76	6" diameter
HDPU	15.41	0.51435	50.21	11.98	3.998" diameter
H602	16.06		53.19	11.09	MI beampipe
Quad 602	17.29		56.54	10.16	MI beampipe
*H Schottky	19.54	0.6069	48.99	11.87	4.875" diameter
*H trans. WB	21.13	1.59004	42.32	14.16	4.33" diameter
*spool	22.49		37.11	16.56	6" diameter
*RWM (+absorber)	24.27	1.78702	30.90	20.42	4.715"W x 2"H
*spool	24.41		30.46	20.74	6" diameter
*PINGER	26.15	1.74625	25.18	25.28	5.25"W x 1.5"H
DCCT	27.22	1.0668	22.31	28.40	4.75" diameter
spool	29.77		16.27	37.46	6" diameter
V trans WB	31.36	1.59004	13.50	43.62	4.33" diameter
spool	31.50		13.29	44.19	6" diameter
V Schottky	32.18	0.6069	12.41	46.72	4.875" diameter
VDPU	32.69	0.51435	11.73	48.93	3.998" diameter
Quad 603	34.58		10.25	55.08	MI beampipe
RF cavities					5" diameter
Spool					6" diameter
HDPU	~50	0.51435	52	12	3.998" diameter
H604	50.63		55.6	11.7	MI beampipe
Quad 604	51.866		59.07	11.07	MI beampipe

Table 2. Straight section 601-602 Proposed Layout

	Position	Length	Beta x	Beta y
Quad 601	0		9.87	61.95
VDPU	2.4	0.51435	11.98	52.53
spool	3.93		14.33	45.52
VDK	5.16	1.22555	16.63	40.33
spool	5.29		16.91	39.79
GRIFFEN	6.82	1.53035	20.31	33.91
spool	6.93		20.62	33.49
WBPU (LLRF stipline)	8.52	1.53035	24.84	28.06
spool	8.68		25.28	27.57
Pinger	10.42	1.74625	30.7	22.42
spool	10.56		31.16	22.03
*H trans WB	12.16	1.59004	36.79	18.07
*HDK	13.53	1.22555	42.16	15.16
*HSD	14.90	0.67945	47.93	12.76

HDPU	15.41	0.51435	50.21	11.98
H602	16.06		53.19	11.09
Quad 602	17.29		56.54	10.16
HP602	18.43	0.6069	53.71	10.7
*K602A	20.95	2.2098	42.80	13.98
*spool	21.28		41.48	14.52
*K602B	23.36	2.2098	33.75	18.52
*spool	23.74		32.44	19.36
RWM	25.53	1.787026	26.79	23.76
spool	26.15		25	25.5
DCCT	27.22	1.0668	22.14	28.62
spool	29.84		16.27	37.46
V trans WB	31.35	1.59004	13.50	43.62
spool	31.50		13.29	44.19
V Schottky	32.18	0.6069	12.41	46.72
VDPU	32.69	0.51435	11.73	48.93
Quad 603	34.58		10.25	55.08
RF cavities				
Spool				
HDPU		0.51435		
H604				
Quad 604				

Kicker Power Supply location

The kicker PFN needs a 6 by 12-foot space. An associated relay rack for the power supply and controls is needed. A preliminary inspection of the MI60 South power supply room by Bob Ducar, George Krafczyk, and myself was done. Both of these look like they will fit into the MI60 South power supply room. The PFN could be located against the west wall, in a north-south orientation, of the MI60 South power supply room, being careful not to trap the bus duct.. Currently there are only two penetrations into the MI60 straight section in this room. There is a third penetration just on the other side of the wall separating the power supply room and electronics room that a hole could be cored for a set of cables. The only piece of equipment that might be in the way is the air compressor on the north wall of the power supply room. I have not looked into details concerning conventional power, crates for kicker control, etc. **A detailed layout of the MI60 South power supply room should be completed showing where the power supply and re-located devices would fit.**

Lattice

The lattice through MI-60 straight section is a 90° FODO lattice. Figure 1 shows the lattice functions based upon MI20 MAD lattice file between the center of Q601 and

Q609. The kickers are shown at a distance of 20 meters and the Lambertsons are shown on either side of quad 608 at a distance of about 115 meters.

MI Closed orbit correctors

The MI horizontal and vertical closed orbit correctors have a measured transfer function of 0.007117 T-m/Amp and 0.003149 T-m/Amp, respectively. The maximum design current for the correctors is 15 Amps with the power supplies designed to trip at 18 Amps. This corresponds to 266 ur and 320 μr kick at 120 GeV, respectively. For orbit calculations here, I limit the corrector strengths to 266 μr. If additional correction is needed at 120 GeV, we could utilize quad moves to reduce the magnitude of the corrector current as was done at MI40, MI52, and MI62.

Closed orbit 8 Gev/120 GeV/ Extraction:

I have located the Lambertson septa 4 to 6 mm to the outside of the straight section centerline to increase aperture for circulating beam. A closed orbit bump (either a 3-bump or 4-bump) is required for circulating beam around the Lambertson septa at all energies. This bump should be approximately 25 to 27 mm to the inside of the ring at 8 GeV and shrink to approximately 12 mm at 120 GeV. With the closed orbit program, I50, we can specify desired positions at 8 GeV, acceleration, and flattop.

Since the phase advance between the kicker and Lambertsons is ~ 270 ° and the beam is extracted to the outside (field region of the Lambertson is on the outside of the ring), the kicker must kick to the inside of the ring. To avoid a large orbit distortion through Q604 at extraction one may desire to install a closed orbit bump to the outside centered at Q604. If we use a 10 to 12 mm bump (θ ~ 200 μr), we can reduce the extraction orbit distortion to ~ 15 to 18 mm. *It should be noted that the horizontal damper pick-up is located just upstream of Q604, at the peak of the closed orbit bump. If the dampers are used at flattop, which probably they aren't, this offset will have to be taken into account with the damper gain.* Figure 2 shows the closed orbit at 120 GeV for a 12 mm bump to the inside at Q604, a 11 mm bump to the outside at 608, and a 10 mm bump to the outside at Q610. Note that I use a 4 bump around the Lambertsons rather than a 3 bump. This last bump is used to keep the beam to the inside through the third Lambertson increasing aperture for circulating beam. These bumps are of course not fixed and are considered tunable parameters used to minimize circulating beam losses under normal operation. The correctors used in this example are listed in Table 3. Note here that H610 is running at 15 Amps. If a larger bump is needed then, quad re-alignment is required (as done at MI-52).

Table 3: Corrector angles for Lambertson bump and kicker compensation

Corrector	Angle [μr]
H602	-221.07
H604	-11.91
H606	-4.26

H608	229.89
H610	266.0
H612	258.7

Extraction orbit /Lambertson excitation and rolls

The primary NuMI beamline, as described in TM-1946, follows the MI centerline until approximately 611-612 cell boundary when the bearing matches the bearing to Soudan specified by the Survey and Alignment Group. There should be no other major horizontal bends in the primary beam transport line to the target. The magnet string HV101, made up of 7 EPB magnets, is divided into 3 roll circuits. This string has to be installed between the Main Injector and Recycler and is used to level the beam trajectory while following the footprint of the MI till the proper horizontal trajectory to Soudan is achieved.

The kicker, K602, produces a 565 μr kick to produce a 23.5 mm displacement at the entrance to the first Lambertson, LAM60A. All three Lambertsons are powered in series, each with an angle of 6.25 mr.. The horizontal orbit of the extracted beam out of the c-magnet, V100, and into the NuMI beamline starting at Q101 is adjusted by the roll angles of the Lambertsons and c-magnet (as well as the kickers and closed orbit). The vertical orbit is primarily determined by the Lambertson and c-magnet strengths.

Using the 4-bump discussed above, Figure 3 shows the extraction trajectory through the straight section to the exit of the c-magnet for the **original** Lambertson roll angles as copied from MI-52 and are **close to those used in the NuMI baseline design**. A negative x is to the radially outside of the MI centerline. The roll angles for the original and the modified solution are listed in Table 4. The first Lambertson, LAM60A is rolled by 0.22 mr. toward the outside of the ring to compensate for the quad steering by Q608. However, this roll angle over compensates for the quad steering. The second and third Lambertsons also kick the beam to the outside. The c-magnet again over compensates the steering with its 0.199 mr. roll angle. The result is that the horizontal trajectory at the exit of the c-magnet is 26 mm to the outside with a 0.76 mr angle wrt the MI closed orbit. Figures 4A thru 4E show magnet cross sections and beam ellipses representing +/- 2.5 sigma of a 40 π-mm-mr (95% normalized) beam (both circulating and extracted) at the entrance and exit of the Lambertsons, quad Q608, and the c-magnet for the old roll angles. A positive x is to the outside of the MI. Figure 4B shows the beam at the entrance and exit of the quad aperture as well as the downstream end of LAM60A (dashed line) and the upstream end of LAM60B (dotted line).

By **reducing** the roll angle of all the Lambertsons and c-magnet (see table 4, modified rolls) a trajectory at the exit of the c-magnet that is parallel to the MI closed orbit is attained. Also, the horizontal trajectory through the quad Q608 is reduced and the aperture for the circulating beam can be increased. The extraction trajectory that results from the modified Lambertson roll angles are shown in Figure 5. Figure 6 shows the horizontal beam envelope at 120 GeV/c for a 40 π-mm-mr beam and the location of the Lambertson septa with respect to the MI centerline. Here, the outside of the ring is to negative x. Figures 7A thru 7E show the magnet cross sections and beam ellipses for the solution with the reduced roll angles. In Figure 7A, LAM60A is shown as not being parallel to the MI60 straight section. The upstream edge (solid line) of the field region is at 6 mm while the downstream edge (dashed line) is at 8 mm. This Table 5 summarizes the trajectories at the entrance to the LAM60A, exit of the Quad, the position detector HP608, and the exit of the c-magnet, V100. The exit of the c-magnet represents the entrance into Q101 of the transport line.

Table 4: Lambertson rolls

Magnet	Original roll	Modified roll	direction
	[mr]	[mr]	
LAM60A	-0.22	-0.124	wall side down
LAM60B	-0.0864	-0.0254	wall side down
LAM60C	-0.037	-0.0254	wall side down
V100A	+0.1995	0.0	aisle side down

Table 5: Extraction orbit positions [mm] and angles [mr] for the original and modified Lambertson and c-magnet roll angles.

Location	Original Roll angles				Modified Roll angles			
	x	x'	y	y'	x	x'	y	y'
entrance LAM60A	-15	-.55	0	0	-15	-.55	0	0
exit LAM60A	-19.0	-1.92	9.94	6.1	-18.0	-1.33	10.1	6.2
exit Q608	-21.5	-.13	25.1	7.62	-19.3	.32	25.5	7.75
HP608	-21.5	-.13	26.5	7.62	-19.3	.32	26.9	7.75
exit V100	**-25.9**	**.76**	**213.**	**28.3**	**-18.2**	**0**	**215**	**28.65**

Impact of modified roll angles on beamline and fitting choices

The change in the transverse positions and angles at the exit of the extraction c-magnet impact the trajectory into the NuMI transport line starting at Q101. Since the trajectory into Q101 is different (see exit V100 in Table 5), the upstream end of the transport line will need to be adjusted. There are several options to accomplish this. Options A thru D only vary the position, roll angle, and strength of the EPB string, HV101(1-7) to fix the trajectory at the first quad, Q102, downstream of the EPB string, Option D, on the other hand only modifies the tilt of the last three magnets in the EPB string and adjusts the strength of the vertical bend strings V105 and V109 in addition to adjusting the drift between the near and far detector.

- Option A: Keep the position of the quads Q102 and Q103 fixed and define the pitch, elevation, and bearing to Soudan.
  - Fit: X, Z, elevation (Y); pitch; and bearing to Soudan from Alignment and Survey
  - Vary: HV101 angle; the tilt of HV1013,4 (tiltc2); the tilt of HV1015,6,7 (tiltc3); the drift between Q101 and HV1011 (DQ1D); and the drift between HV1017 and Q102 (DQ2U).
  - This does not modify the roll angle of the first two EPB magnets (they remain horizontal only) and localizes any changes to the 7 EPB magnets.
- Option B: Same constraints as Option A except adjust roll angle of the first four EPB magnets.
- Option C: Let the transverse position of the upstream EPB's, Q102, and Q103, vary (keeping them above the MI footprint) but define the pitch, elevation, and bearing to Soudan.
  - Fit: elevation (Y); pitch; and bearing to Soudan from Alignment and Survey
  - Vary: HV101 angle; the tilt of HV1013,4 (tiltc2); the tilt of HV1015,6,7 (tiltc3)
- Option D: Same constraints as C except adjust the roll angle of the first four EPB magnets to reduce the magnitude of the required roll.
- Option E: Let the position of the quads Q103 and Q103, pitch, and elevation vary but define the coordinates at Soudan.
  - Fit: the elevation of the target and the X, Y, and Z at the detector in Soudan in the Main Injector plane and let the pitch and elevation at Q102 be unconstrained.
  - Vary: the tilt of HV1015,6,7 (tiltc3); angle of V105 down bend; the angle of V109 up bend in pre-target hall and the drift length between the near and far detectors, ILWIMN.

The central trajectories and the magnet placement for these should be compared to the base-line design to determine the impact on stand placement.

Table 6: A summary of the required changed to the position, roll angle, and strength of the devices needed to compensate for the change in the Lambertson and c-magnet roll angles. The dashes mean value was not used for fitting.

Device	CURRENT	Option A	Option B	Option C	Option D	Option E
HV101	-10.5026	-9.92258	-10.0334	-10.1874	-10.3240	---
HV1011,2 tilt	0.0	---	-.11320	---	-.061553	---
HV1013,4 tilt	-.05726	-.29610	-.11320	-.17546	-.061553	---
HV1015-7 tilt	-.99878	-.87321	-.926838	-.960593	-1.00000	-.972781
drift Q1D	5.14582	5.79879	5.96152	---	---	---
drift Q2U	1.83283	1.42979	1.26701	---	---	---
V105	-27.0955	---	---	---	---	-27.5597
V109	10.90268	---	---	---	---	11.00729
drift ILWIMN	734263.33	---	---	---	---	734263.357

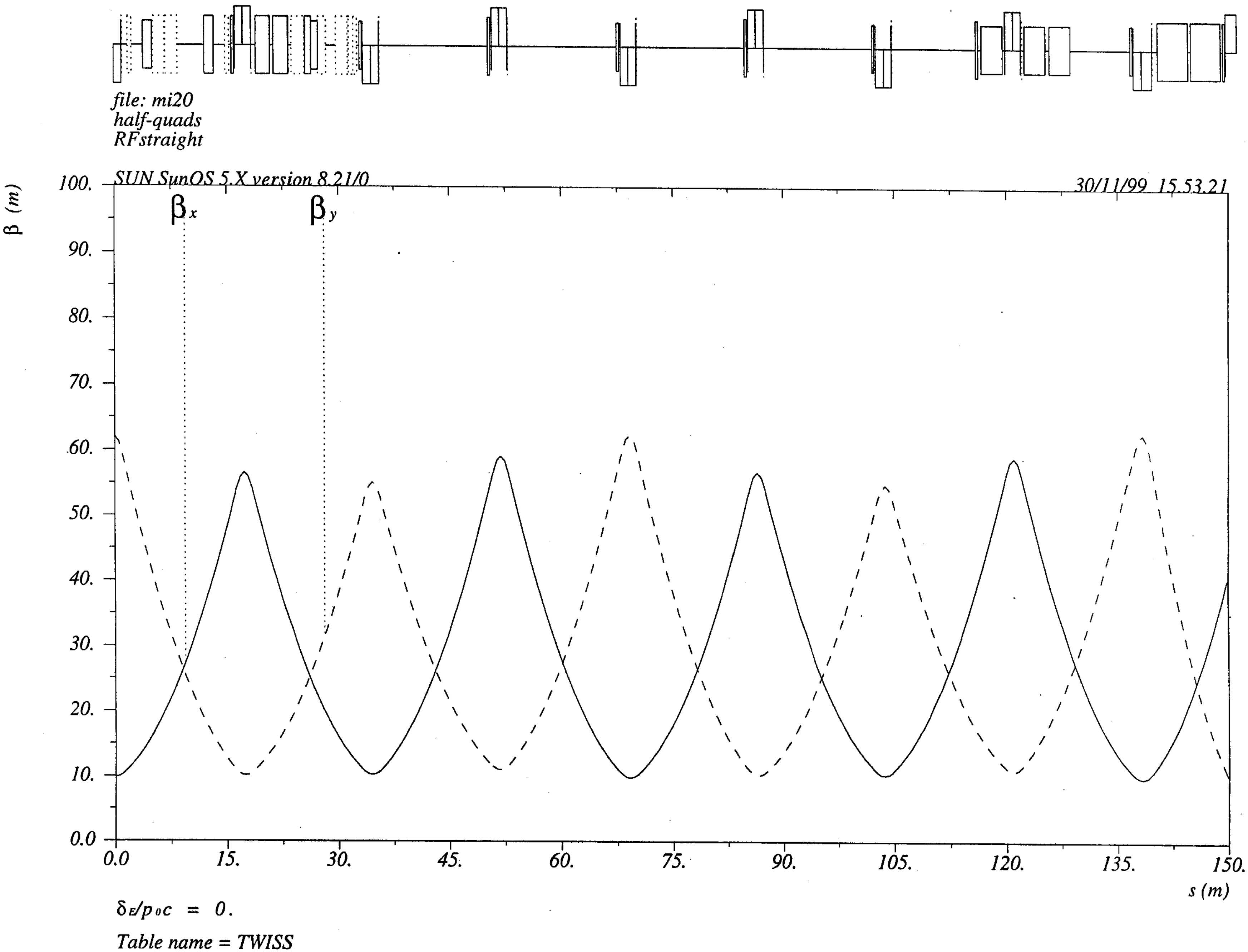
Summary

The required strength for NuMI single turn extraction can be met by a duplicate of the MI-52 multimode kicker. This kicker should have a pulse length of 10.6 μsec. to extract up to six batches. The kickers should be placed 20 inches downstream of Q602 steel. The horizontal Schottky detector and transverse wide band pick up are to be moved upstream of Q602. The pinger is to be removed and rebuilt. Other modifications to the vacuum have been noted. The kicker power supply will be located in the MI60 South power supply room. A detailed layout needs to be done.

Horizontal orbit control bump requirements for circulating and extracted beam have been determined. Apertures have been examined and found not to be a problem.

A suggested modification to the extraction Lambertson and c-magnet roll angles has been outlined which provides a better extraction trajectory and increased vertical aperture for circulating beam. The fitting constraints for specifying trajectory have been examined and new roll angles for the EPB string have been determined. This may have implication on the magnet stands for the EPB string now being made. The magnitude of changes required in the stand design should be determined.

A ramification to implementing single turn extraction rather than resonant is not the horizontal phase space is now that of the MI. Previously the polarity of the Q104,Q105 doublet was such that it minimized the vertical beam size. The polarity of this doublet should change to reduce the horizontal beam size through the rolled B2 vertical bends. The target optics will need to be re-fit. This has been investigated but not reported here.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β (m)
βx
βy
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80.
70.
60.
50.
40.
30.
20.
10.
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15.
30.
45.
60.
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90.
105.
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135.
150.
s (m)
δE/p0c = 0.
Table name = TWISS

Figure 1

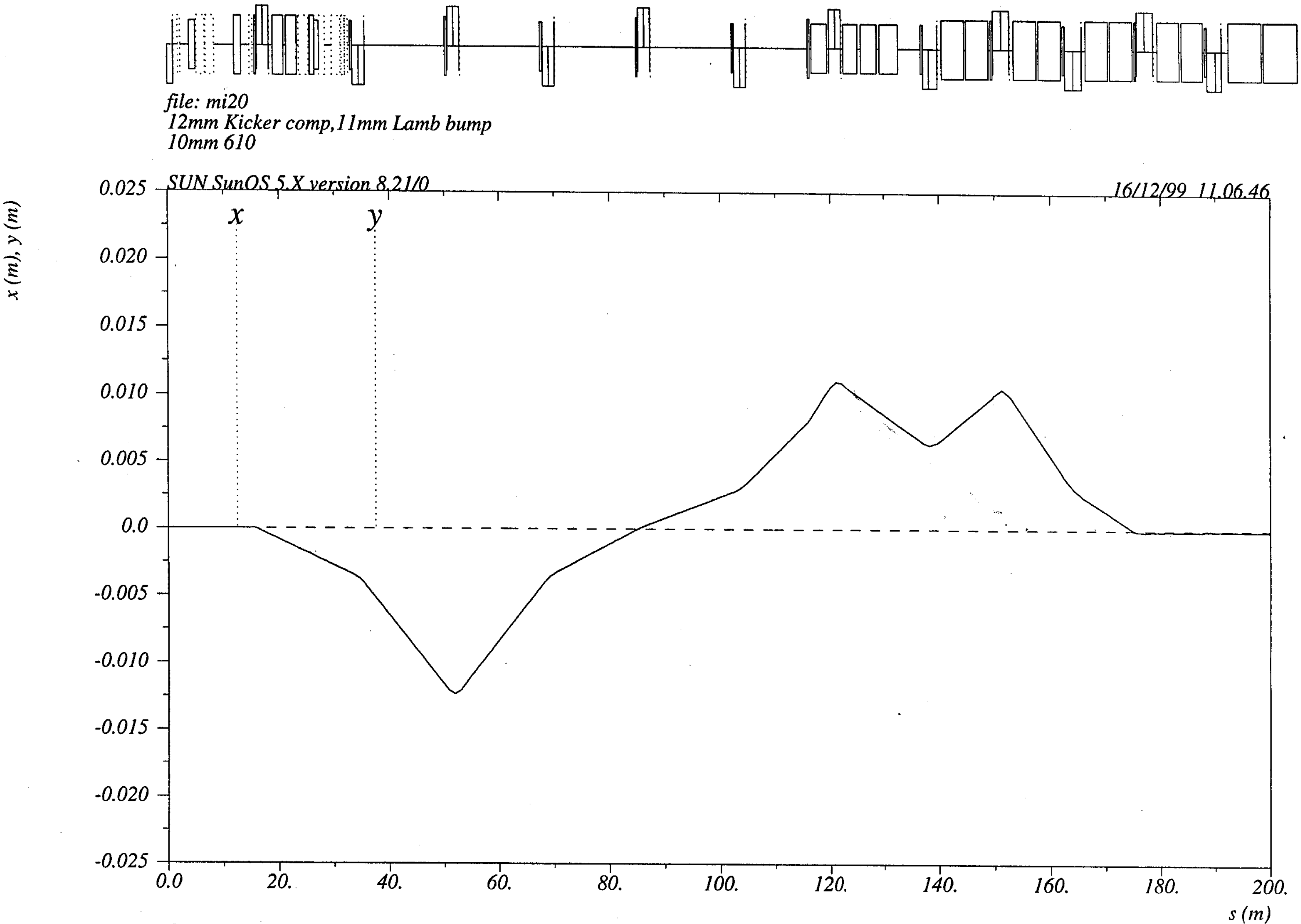

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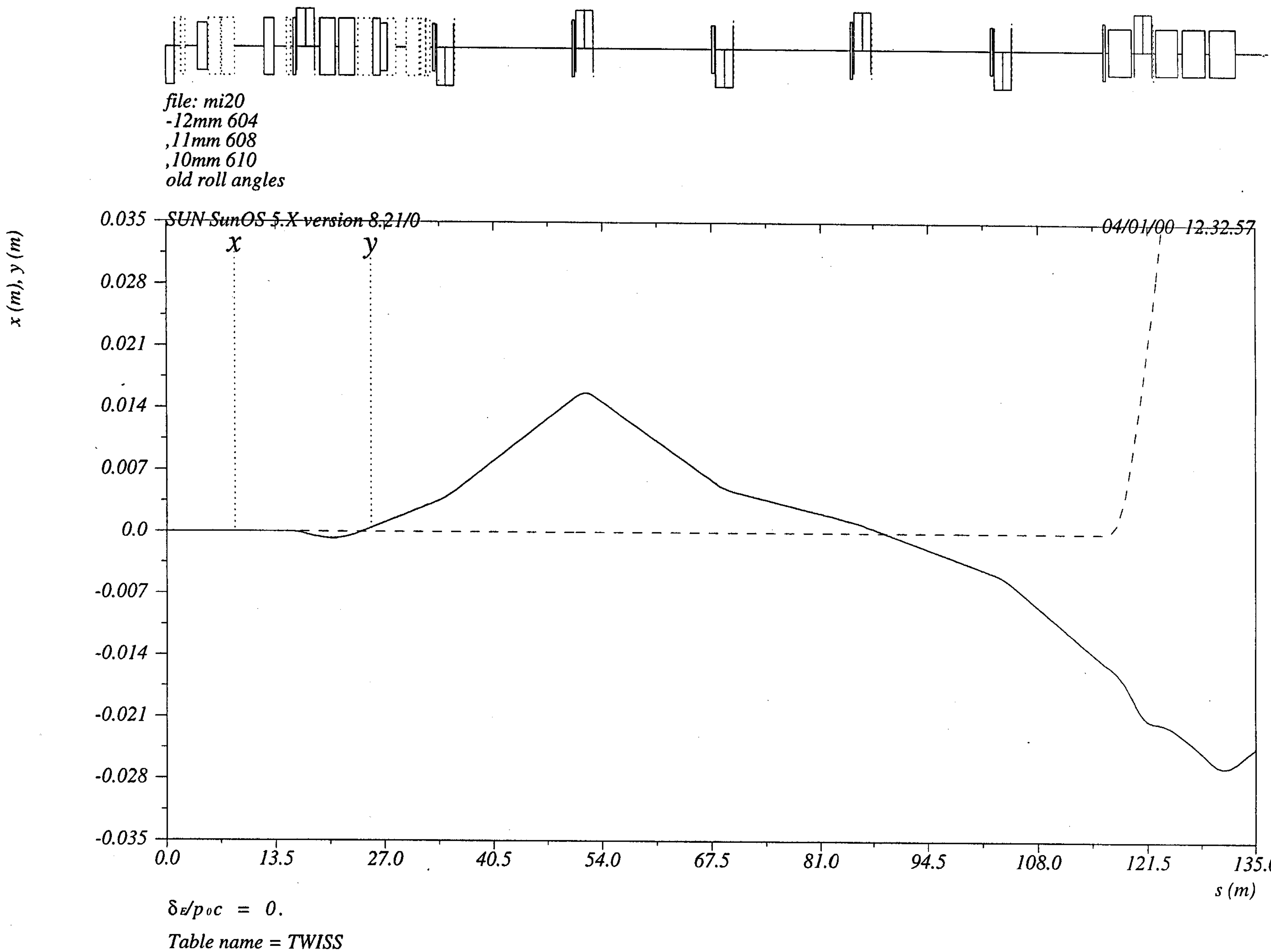
Figure 2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,11mm 608
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old roll angles
SUN SunOS 5.X version 8.21/0
04/01/00 12.32.57
x
y
x (m), y (m)
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0.028
0.021
0.014
0.007
0.0
-0.007
-0.014
-0.021
-0.028
-0.035
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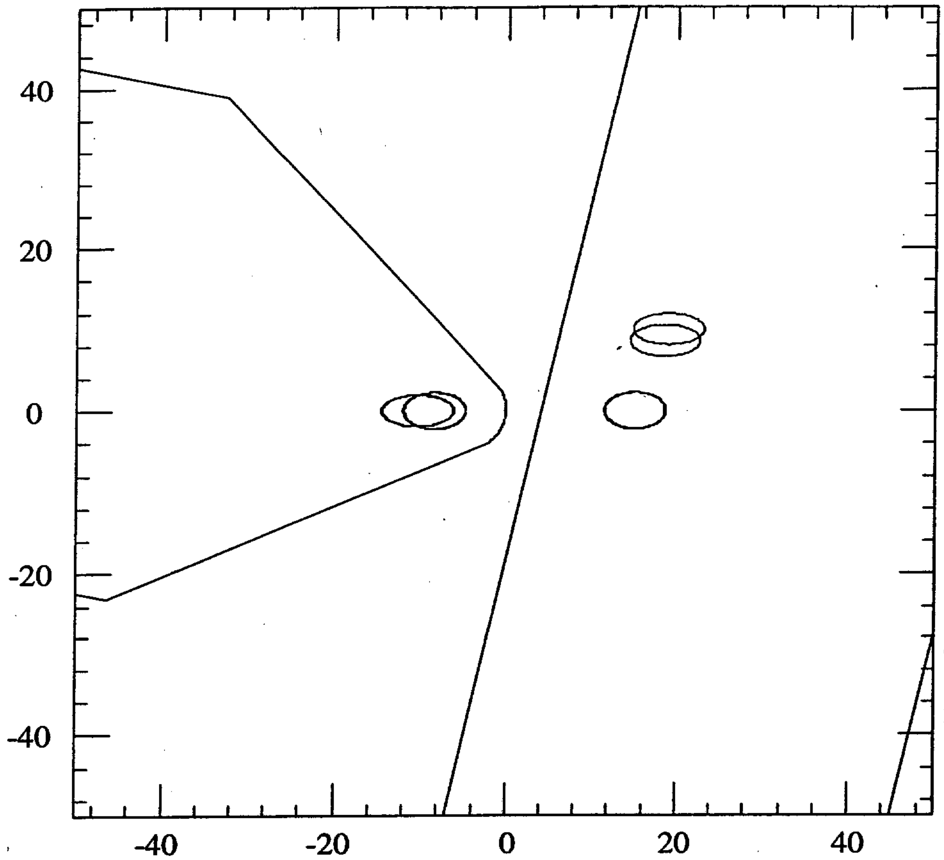
Table name = TWISS

Figure 3

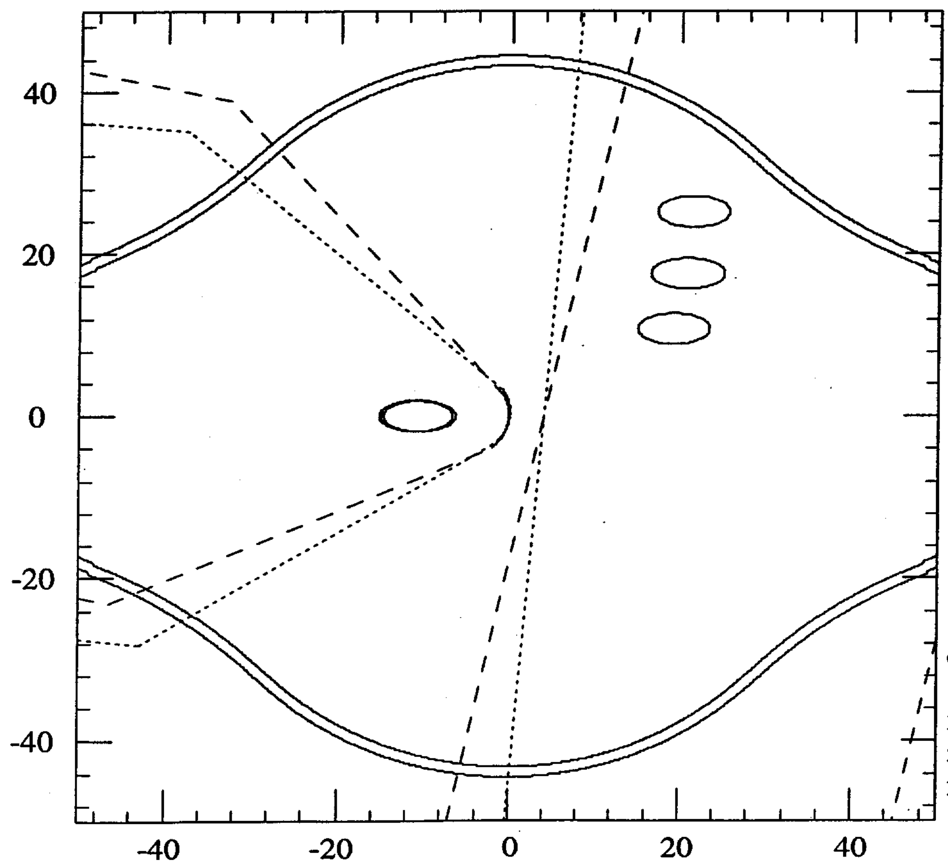


LAM60A	116.566	-8.384	0.000
LAM60A	116.796	-8.533	0.000
LAM60A	119.596	-10.341	0.000
LAM60A	119.596	-10.341	0.000
LAM60A	119.827	-10.490	0.000
LAM60A	116.566	15.000	0.000
LAM60A	116.796	15.127	0.000
LAM60A	119.596	18.584	8.539
LAM60A	119.596	18.584	8.539
LAM60A	119.827	19.026	9.944

element	xoff	yoff	roll	tilt
	[mm]	[mm]	[deg]	[mm]
MILAM	4.000	-1.000	12.610	0.000

Tue Jan 18 08:10:09 2000 FILE: old_rolls_xc_data

Figure 4A

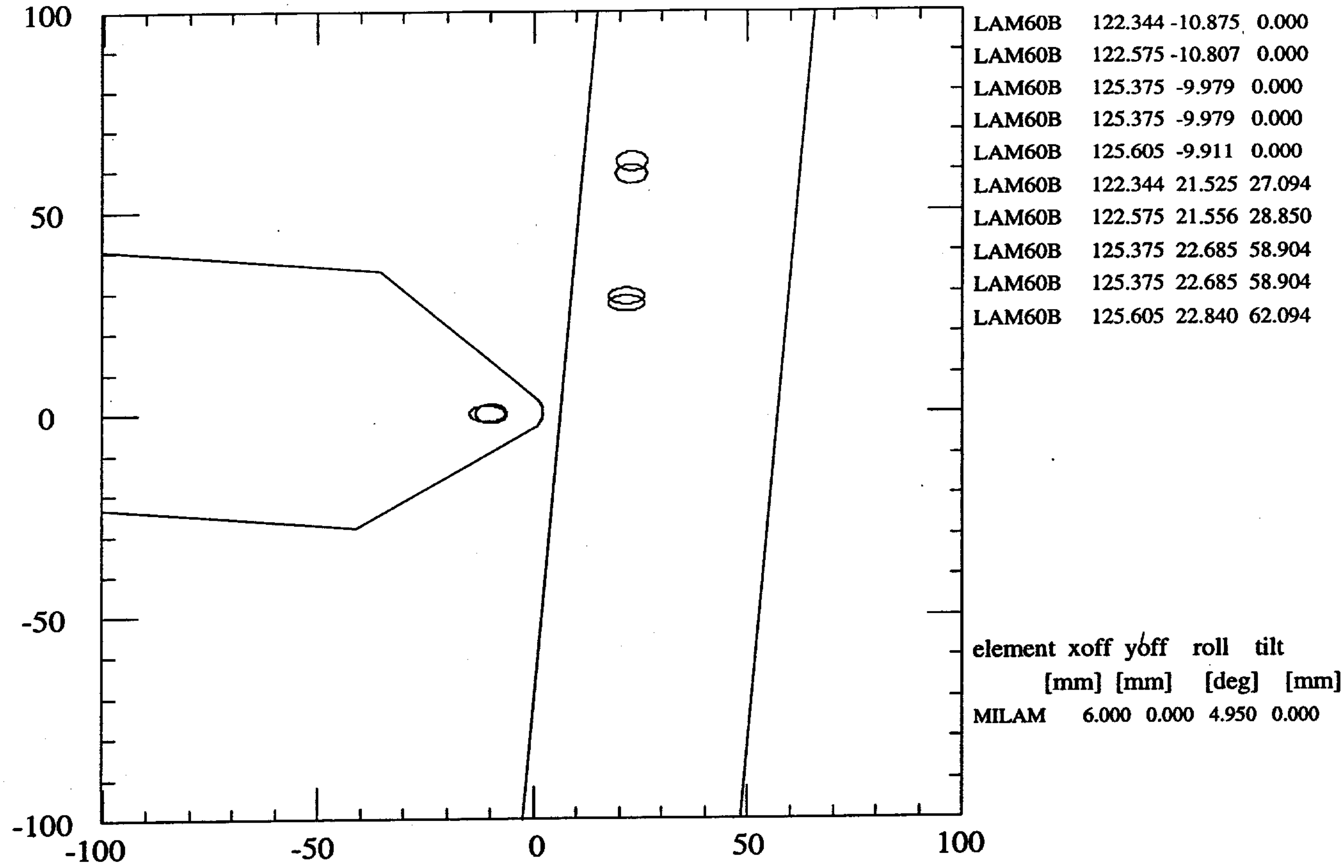


Q608	119.954	-10.572	0.000
Q608	121.020	-11.014	0.000
Q608	121.020	-11.014	0.000
Q608	122.087	-10.951	0.000
Q608	119.954	19.269	10.719
Q608	121.020	20.858	17.523
Q608	121.020	20.858	17.523
Q608	122.087	21.491	25.135

element	xoff	yoff	roll	tilt
	[mm]	[mm]	[deg]	[mm]
MILAM	4.000	-1.000	12.610	0.000
3Q84N	0.000	0.000	0.000	0.000
MILAM	4.000	0.000	4.950	0.000

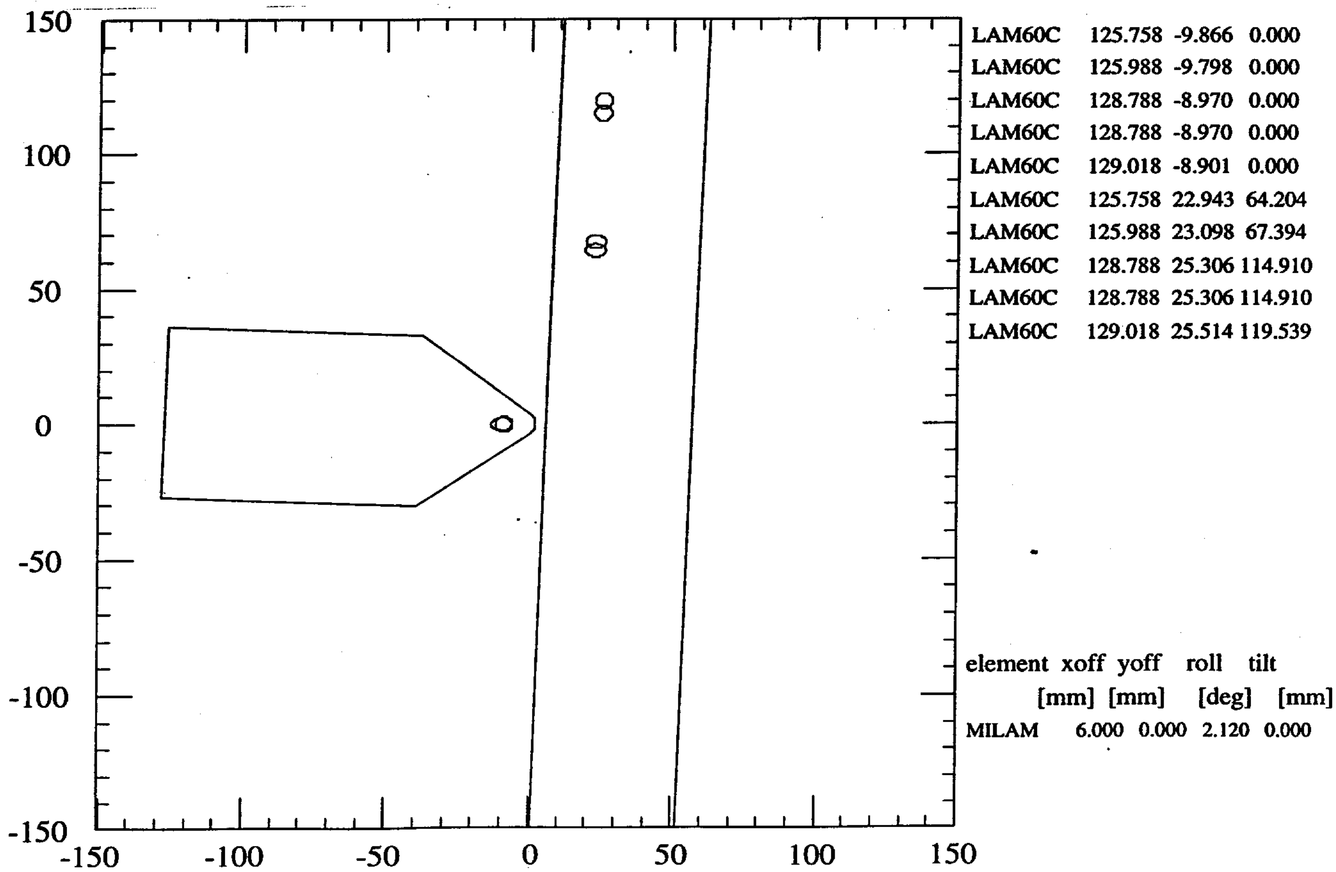
Tue Jan 18 08:10:13 2000 FILE: old_rolls_xc_data

Figure 4B



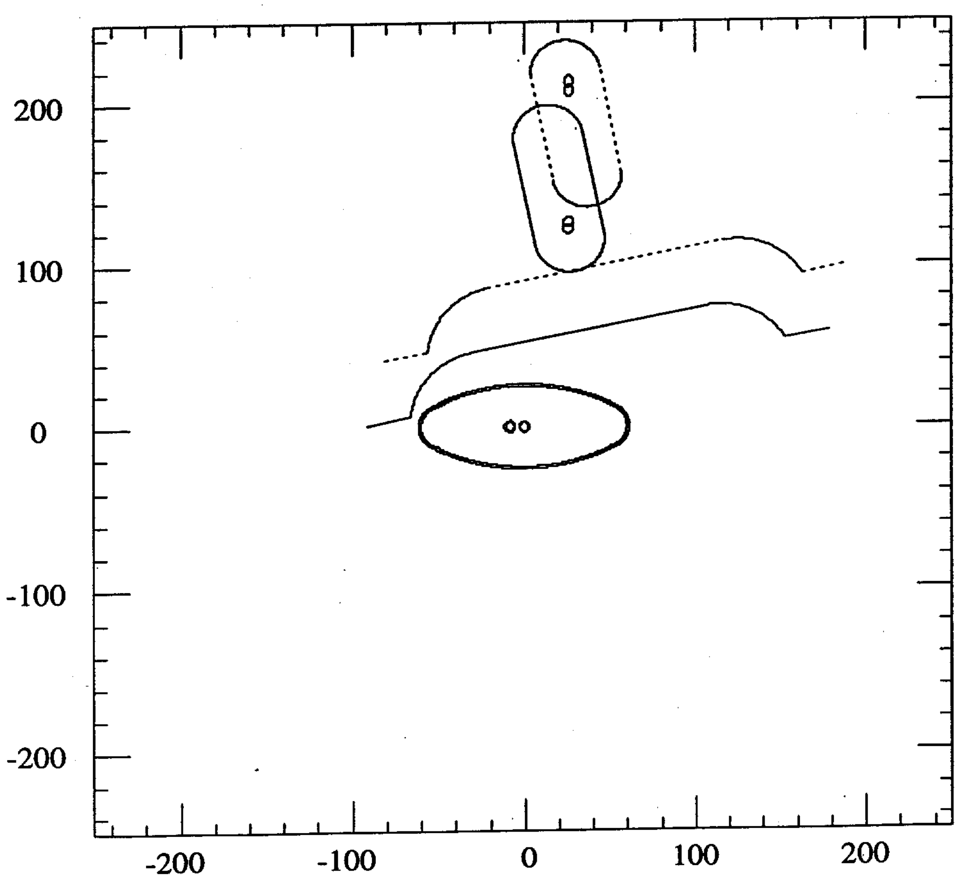
Tue Jan 18 08:10:18 2000 FILE: old_rolls_xc_data

Figure 4C



Tue Jan 18 08:10:20 2000 FILE: old_rolls_xc_data

Figure 4D



V900	129.145	-8.864	0.000
V900_END	129.348	-8.804	0.000
V900	132.701	-7.812	0.000
V900_END	132.904	-7.752	0.000
V900	132.904	-7.752	0.000
V900_INS	281.941	0.039	0.000
V900_END	282.144	0.041	0.000
V900	285.497	0.061	0.000
V900_END	285.700	0.062	0.000
V900_INS	285.700	0.062	0.000
V900	129.145	25.629	122.091
V900_END	129.348	25.813	126.173
V900	132.701	26.054	207.343
V900_END	132.904	25.899	213.099
V900	132.904	25.899	213.099

element	xoff [mm]	yoff [mm]	roll [deg]	tilt [mm]
MICMG1	38.000	60.000	-11.450	0.000
MICMG1	48.000	100.000	-11.450	0.000
MIBP	0.000	0.000	0.000	0.000

Tue Jan 18 08:10:23 2000

FILE: old_rolls_xc_data

Figure 4E

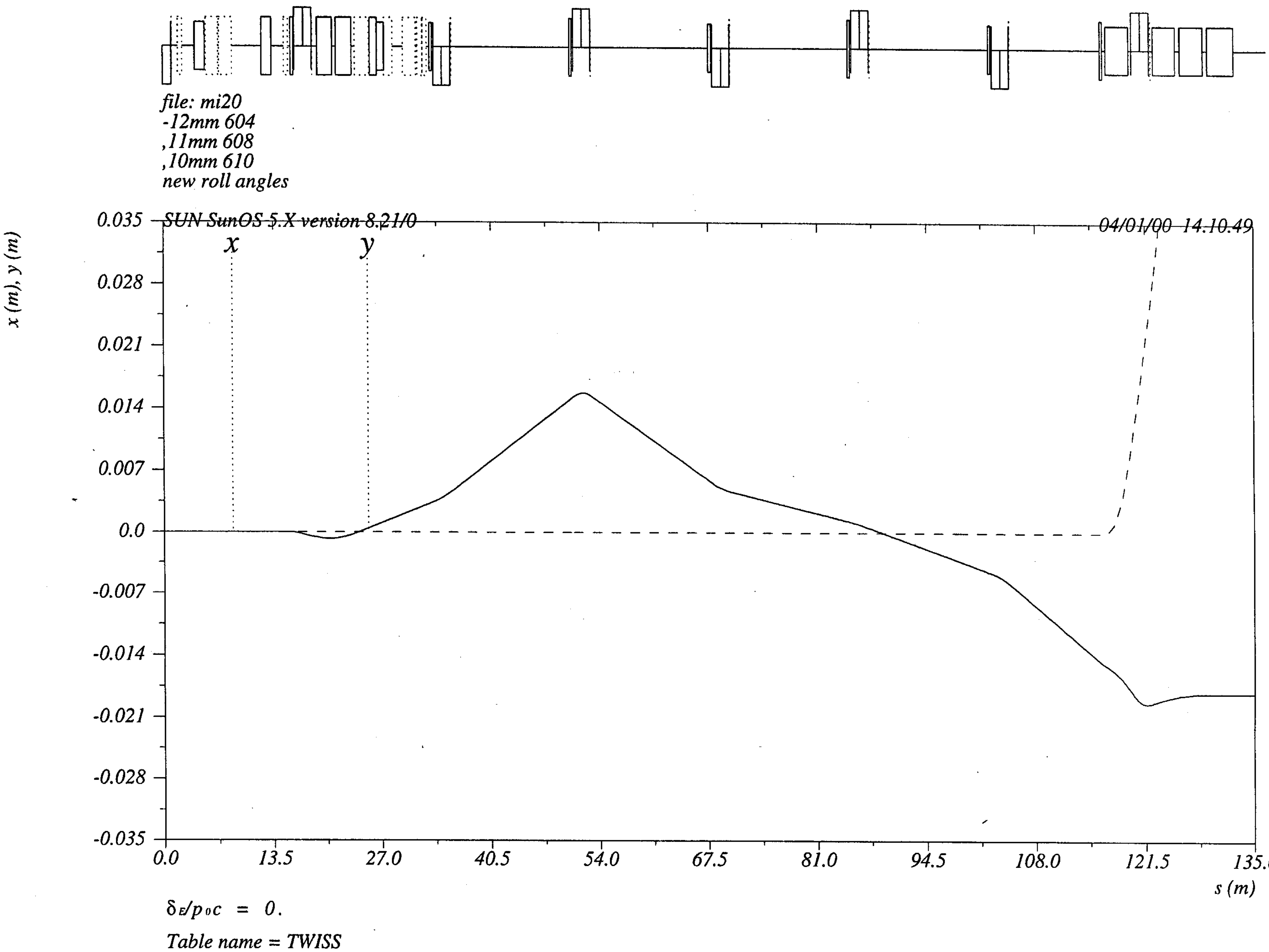
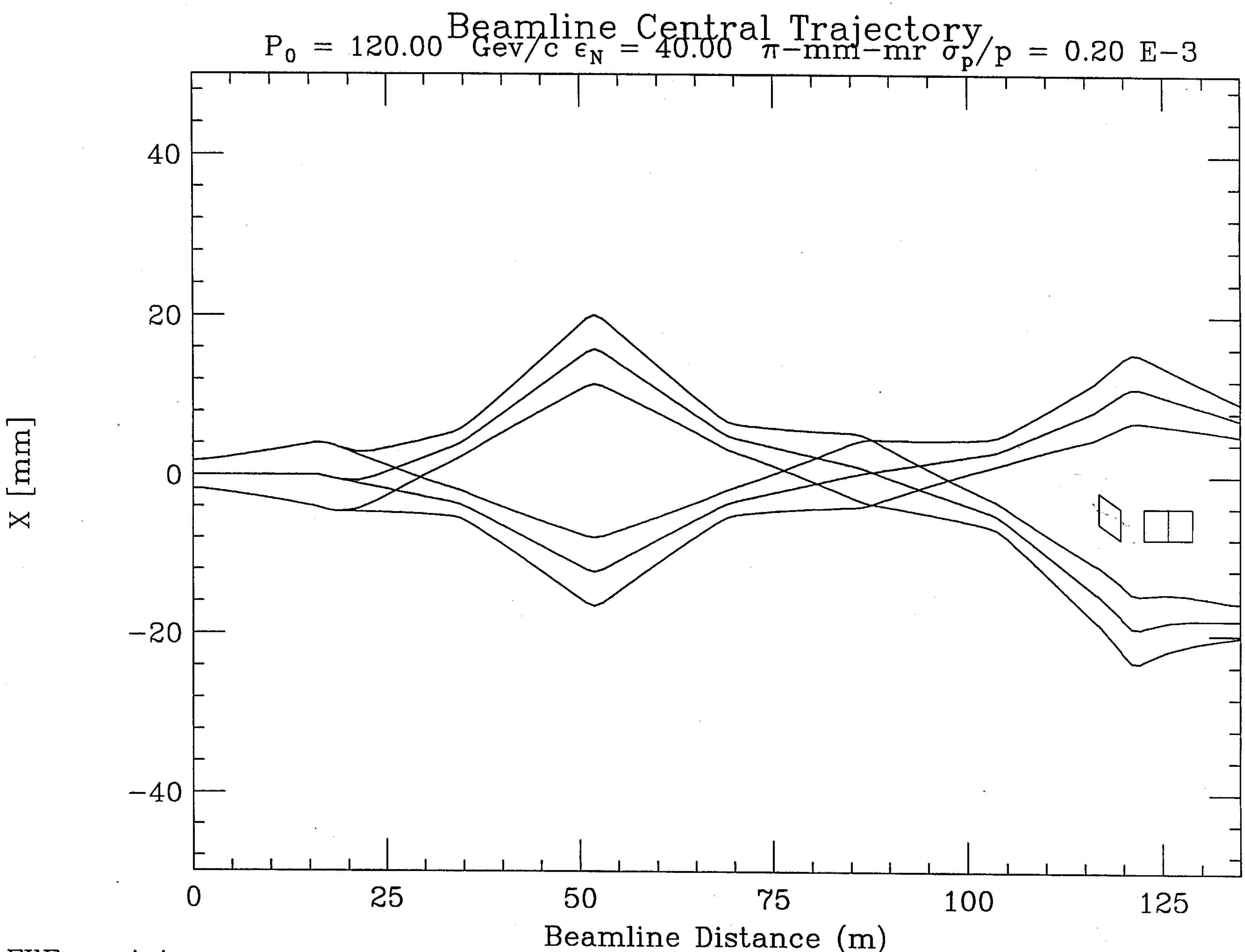

file: mi20
-12mm 604
,11mm 608
,10mm 610
new roll angles
SUN SunOS 5.X version 8.21/0
04/01/00 14.10.49
x
y
x (m), y (m)
0.035
0.028
0.021
0.014
0.007
0.0
-0.007
-0.014
-0.021
-0.028
-0.035
0.0
13.5
27.0
40.5
54.0
67.5
81.0
94.5
108.0
121.5
135.0
s (m)
δE/p0c = 0.
Table name = TWISS

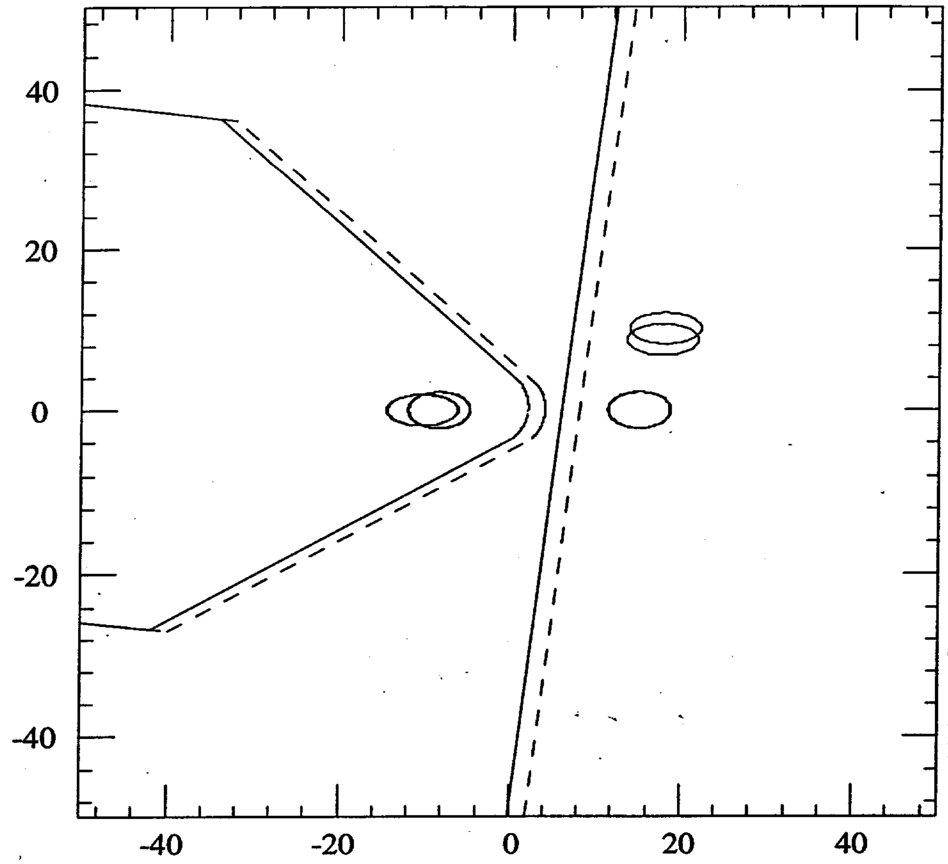
Figure 5



FIlE: print
COMMENT: Closed orbit with Numi extraction

Thu Dec 16 11:10:21 1999

Figure 6

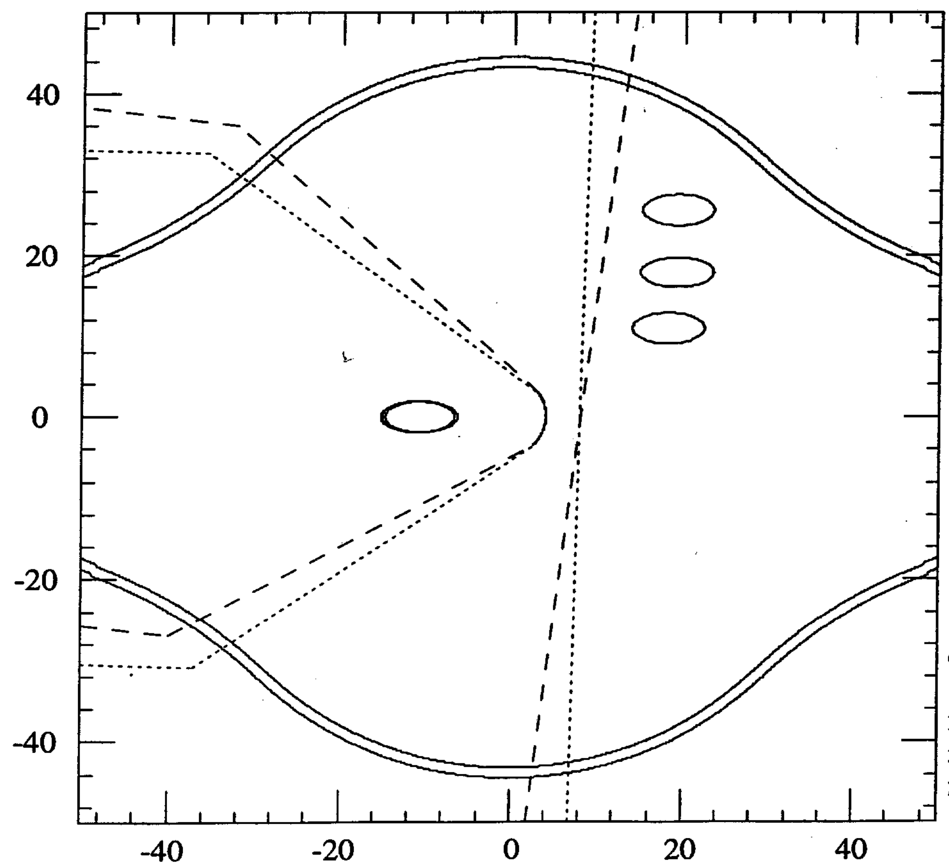


LAM60A	116.566	-8.384	0.000
LAM60A	116.796	-8.533	0.000
LAM60A	119.596	-10.341	0.000
LAM60A	119.596	-10.341	0.000
LAM60A	119.827	-10.490	0.000
LAM60A	116.566	15.000	0.000
LAM60A	116.796	15.127	0.000
LAM60A	119.596	17.757	8.683
LAM60A	119.596	17.757	8.683
LAM60A	119.827	18.063	10.112

element	xoff [mm]	yoff [mm]	roll [deg]	tilt [mm]
MILAM	6.000	0.000	7.110	0.000
MILAM	8.000	0.000	7.110	0.000

Tue Jan 18 08:14:08 2000 FILE: new_rolls_xc_data

Figure 7A

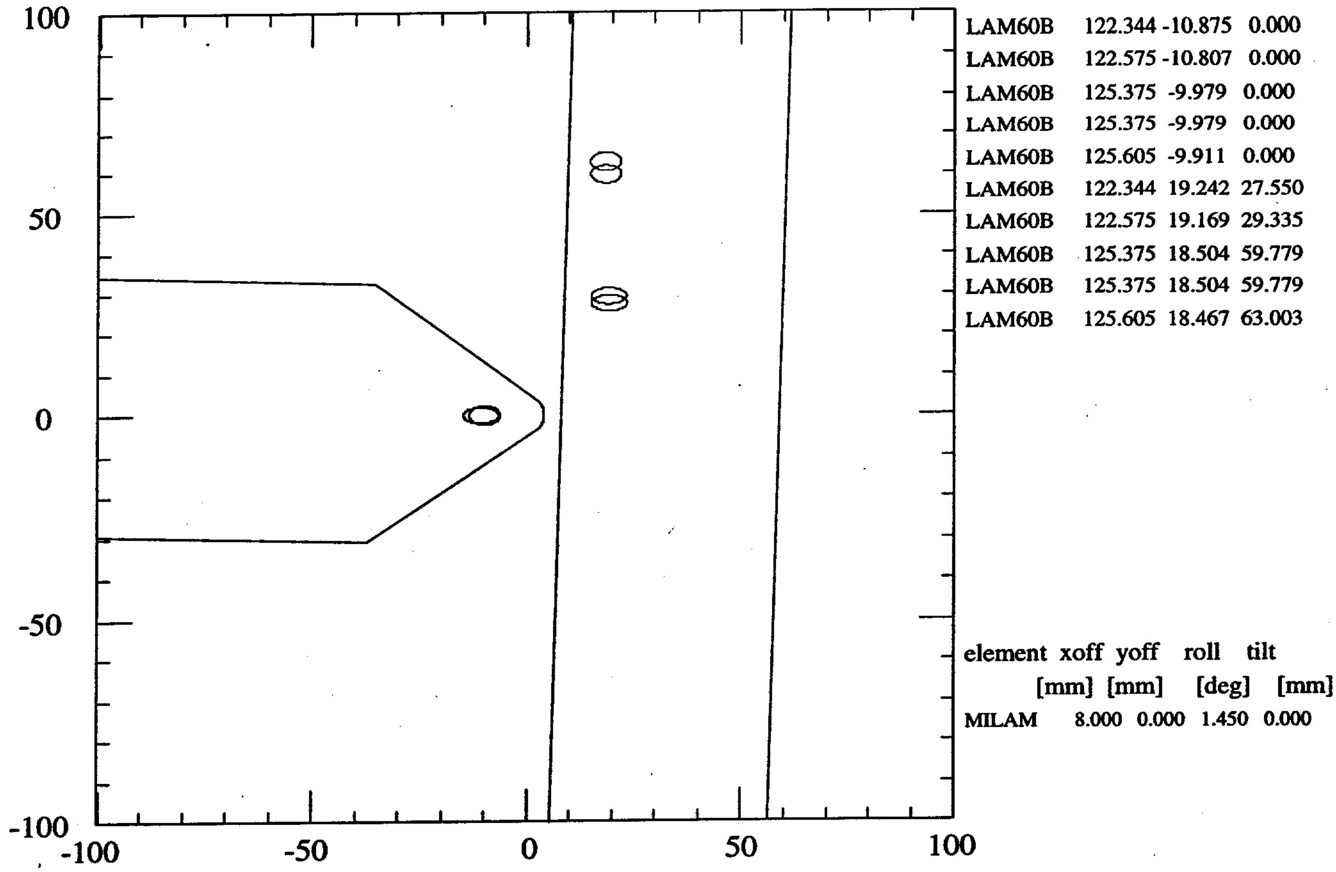


Q608	119.954	-10.572	0.000
Q608	121.020	-11.014	0.000
Q608	121.020	-11.014	0.000
Q608	122.087	-10.951	0.000
Q608	119.954	18.231	10.899
Q608	121.020	19.217	17.818
Q608	121.020	19.217	17.818
Q608	122.087	19.324	25.558

element	xoff [mm]	yoff [mm]	roll [deg]	tilt [mm]
MILAM	8.000	0.000	7.110	0.000
3Q84N	0.000	0.000	0.000	0.000
MILAM	8.000	0.000	1.450	0.000

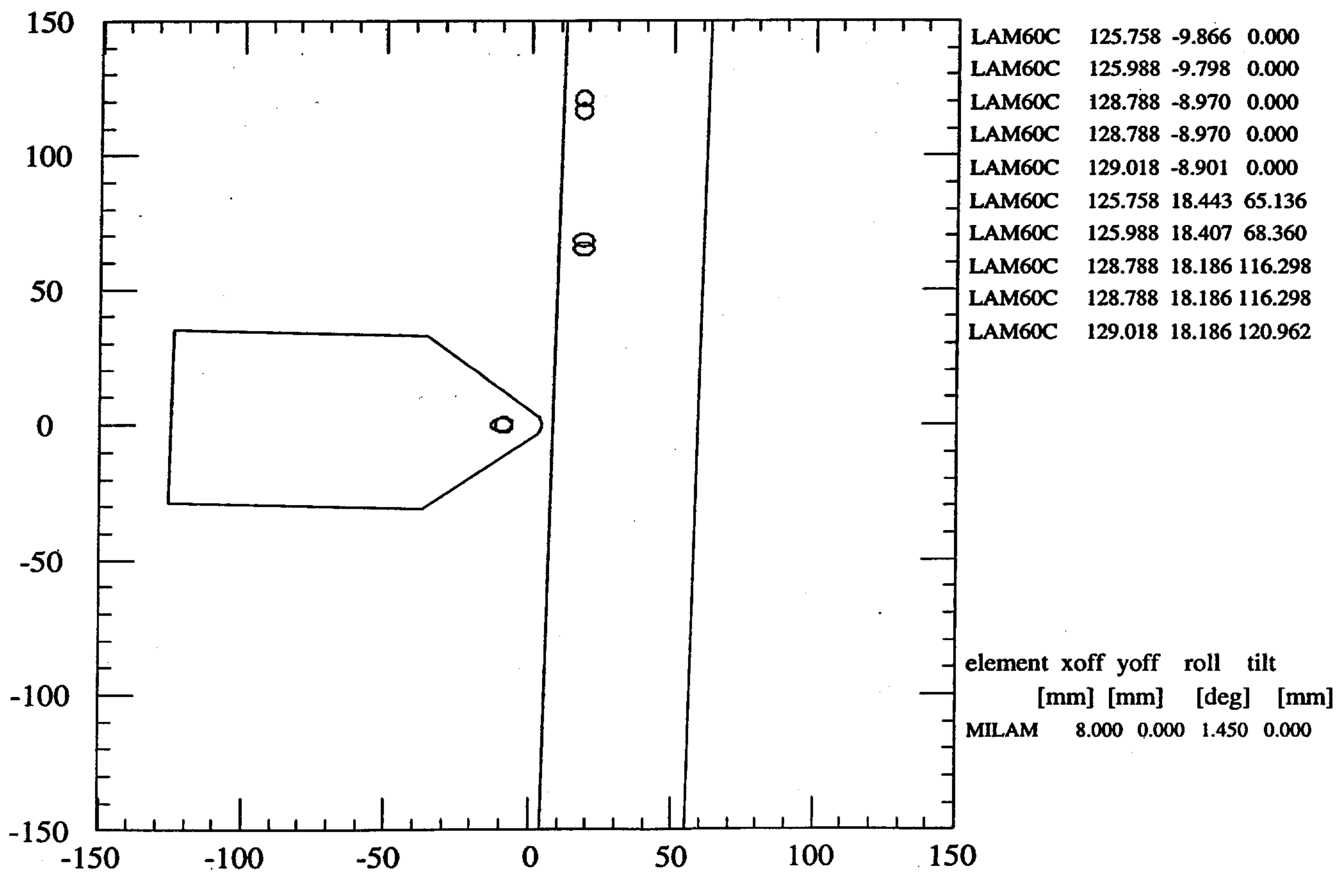
Tue Jan 18 08:14:32 2000 FILE: new_rolls_xc_data

Figure 7B



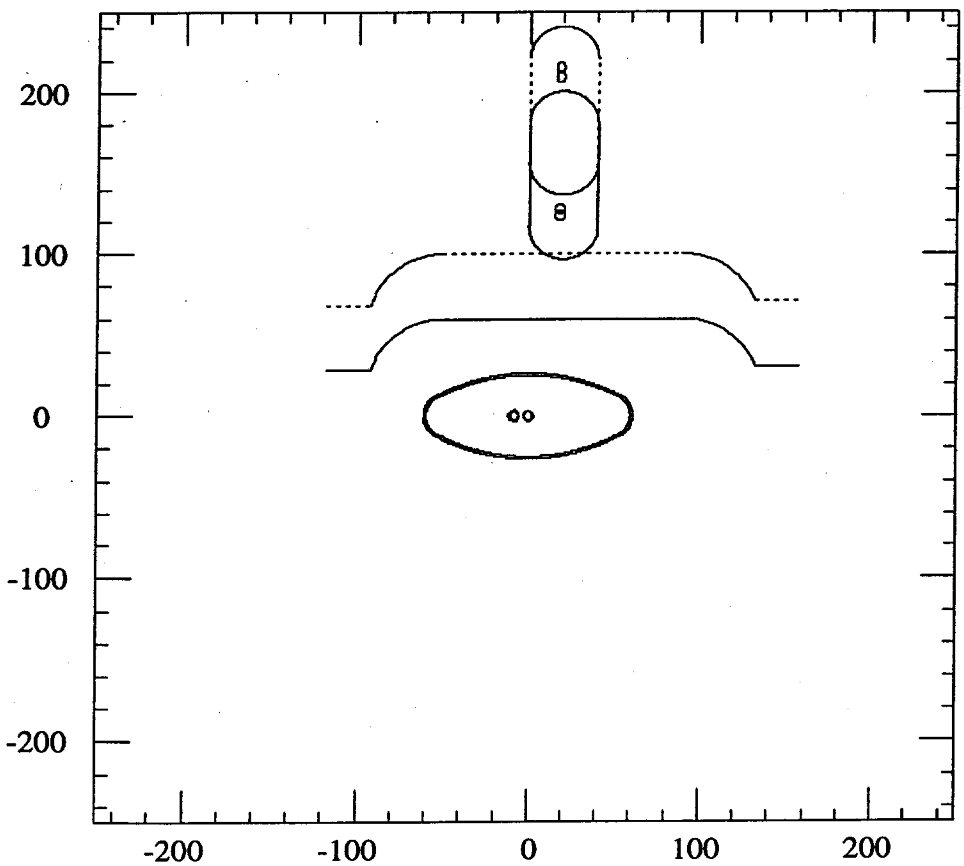
Tue Jan 18 08:14:38 2000 FILE: new_rolls_xc_data

Figure 7C



Tue Jan 18 08:14:41 2000 FILE: new_rolls_xc_data

Figure 7D



V900	129.145	-8.864	0.000
V900_END	129.348	-8.804	0.000
V900	132.701	-7.812	0.000
V900_END	132.904	-7.752	0.000
V900	132.904	-7.752	0.000
V900_INS	281.941	0.039	0.000
V900_END	282.144	0.041	0.000
V900	285.497	0.061	0.000
V900_END	285.700	0.062	0.000
V900_INS	285.700	0.062	0.000
V900	129.145	18.186	123.533
V900_END	129.348	18.186	127.647
V900	132.701	18.188	209.605
V900_END	132.904	18.188	215.425
V900	132.904	18.188	215.425

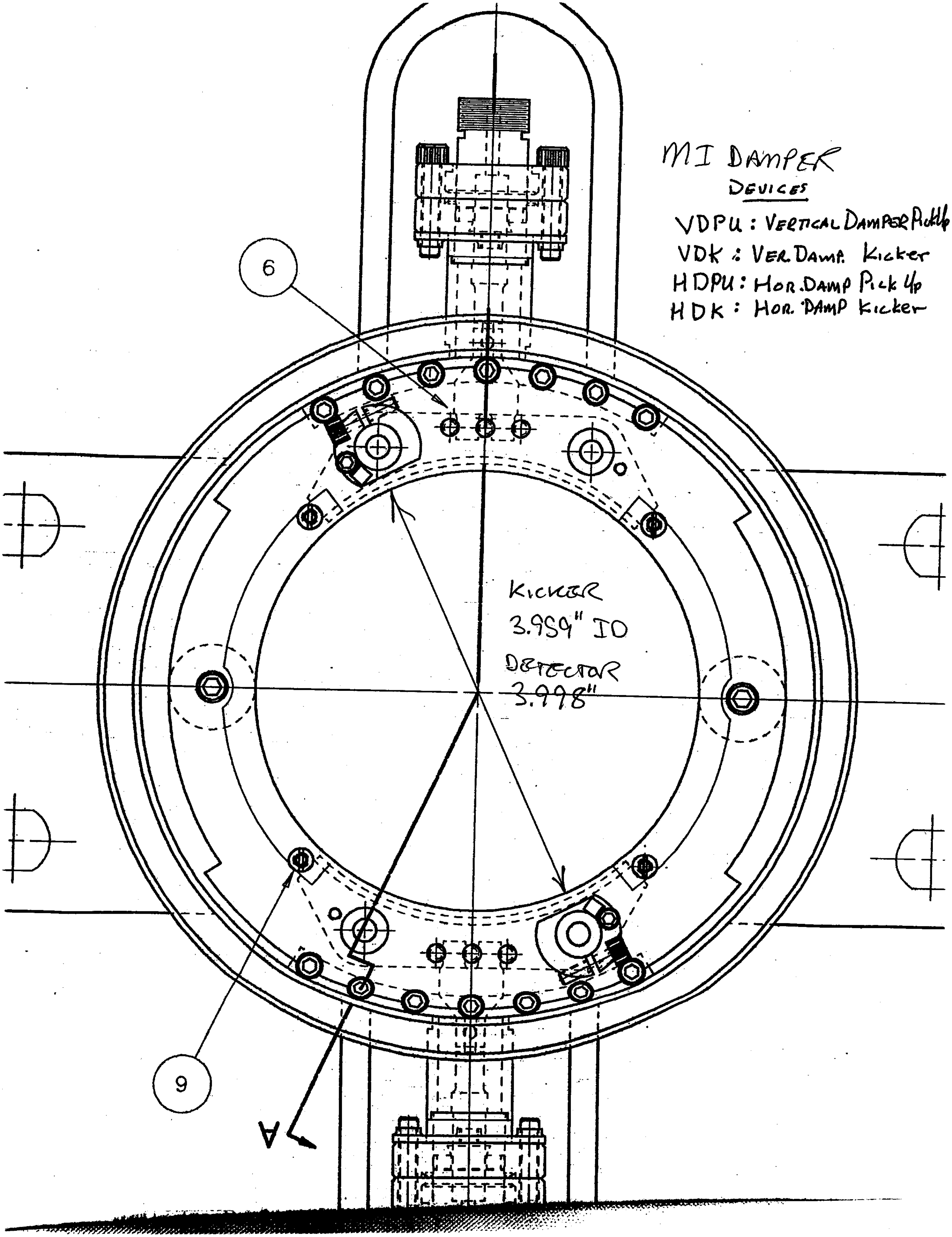
element	xoff	yoff	roll	tilt
	[mm]	[mm]	[deg]	[mm]
MICMG1	20.000	60.000	0.000	0.000
MICMG1	20.000	100.000	0.000	0.000
MIBP	0.000	0.000	0.000	0.000

Tue Jan 18 08:14:44 2000 FILE: new_rolls_xc_data

Figure 7E

MI DAMPER
DEVICES

VDPU : VERTICAL DAMPER PickUp
VDK : VER. DAMP. Kicker
HDPU : HOR. DAMP Pick Up
HDK : HOR. DAMP Kicker



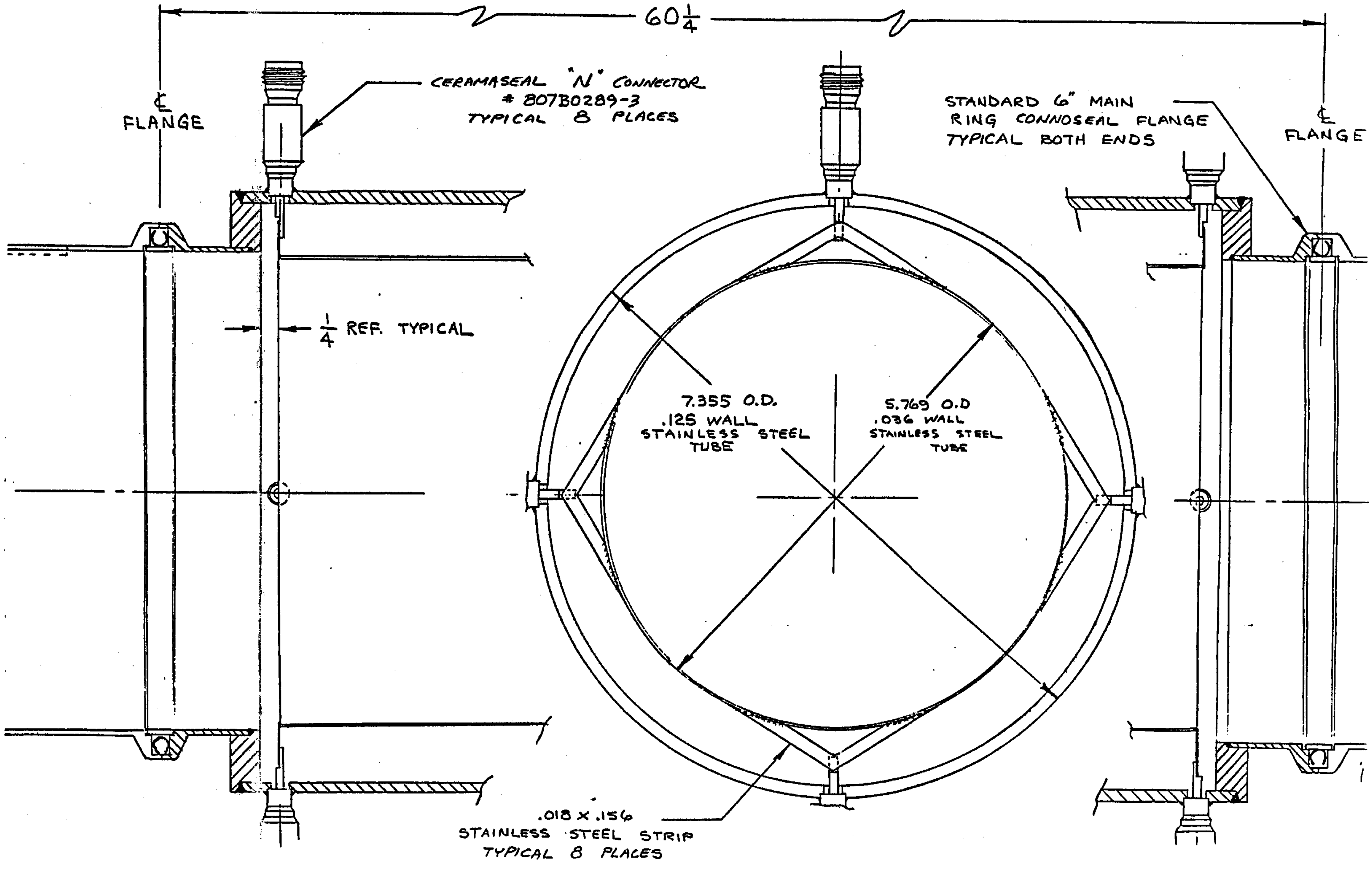
NULL AT $n\frac{\lambda}{2} = \frac{l}{\quad}$

$\frac{nc}{fx} =$

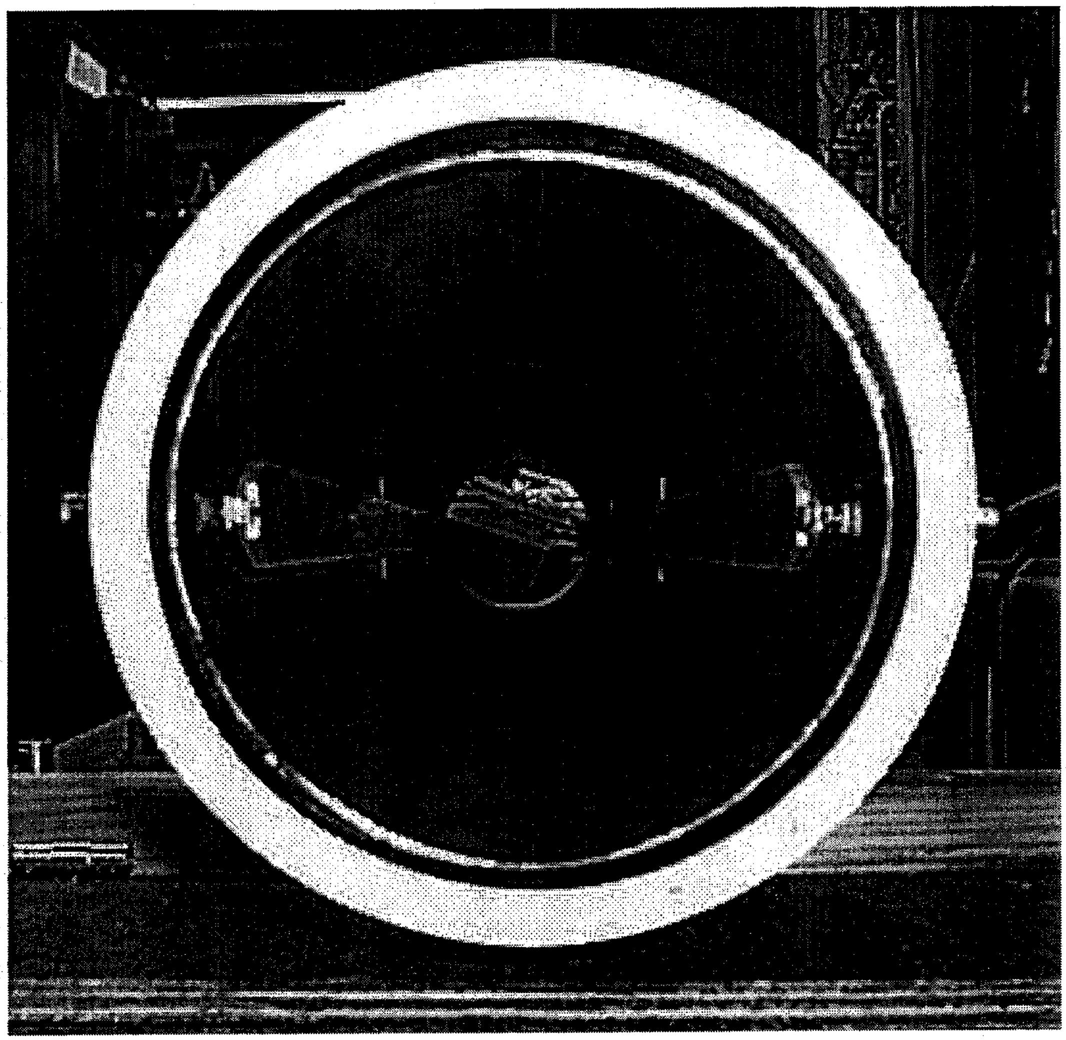
GRIFFIN DETECTOR
E48 MAIN RING

$\frac{1}{4}\lambda = 55.564''$

$\frac{1}{2}\lambda = 111.127''$



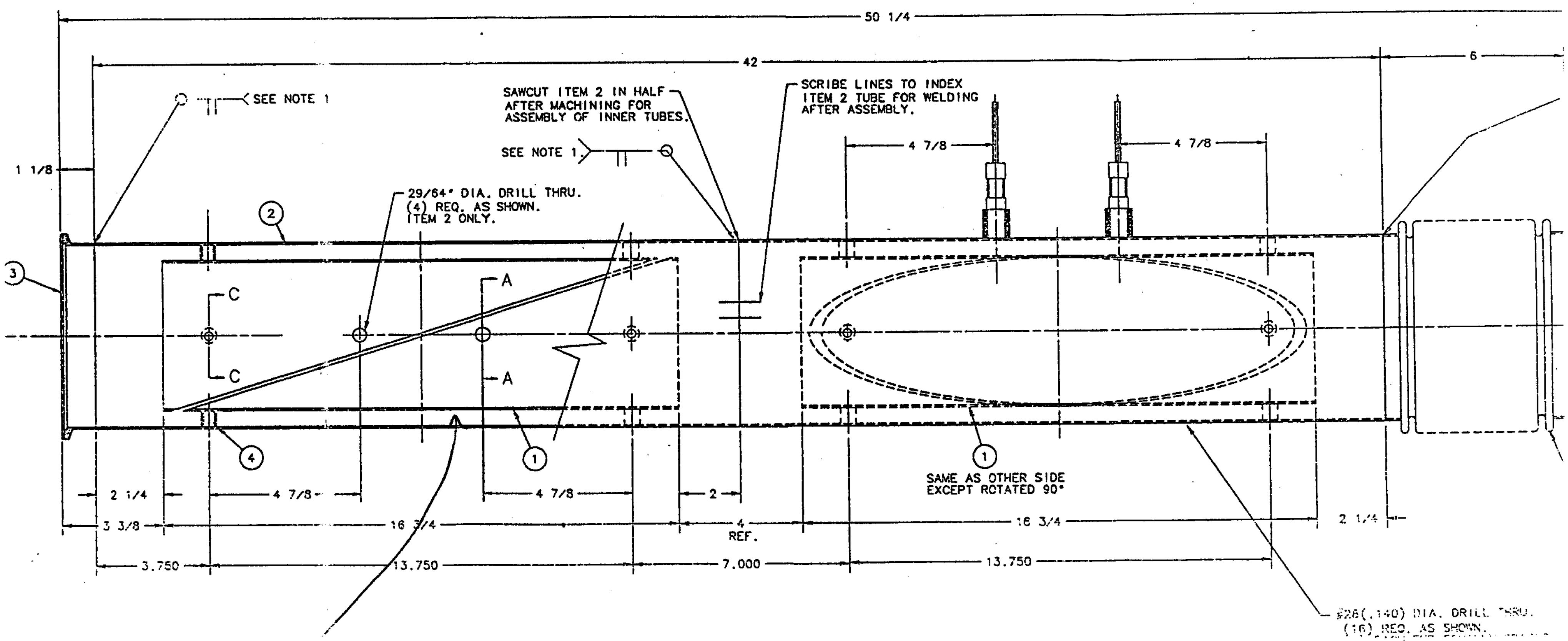
MI LLRF stripline



6" OD 11 gauge pipe
6" quick disconects
1.529m flange to flange
1.426m plate length
120mm inside plate diameter

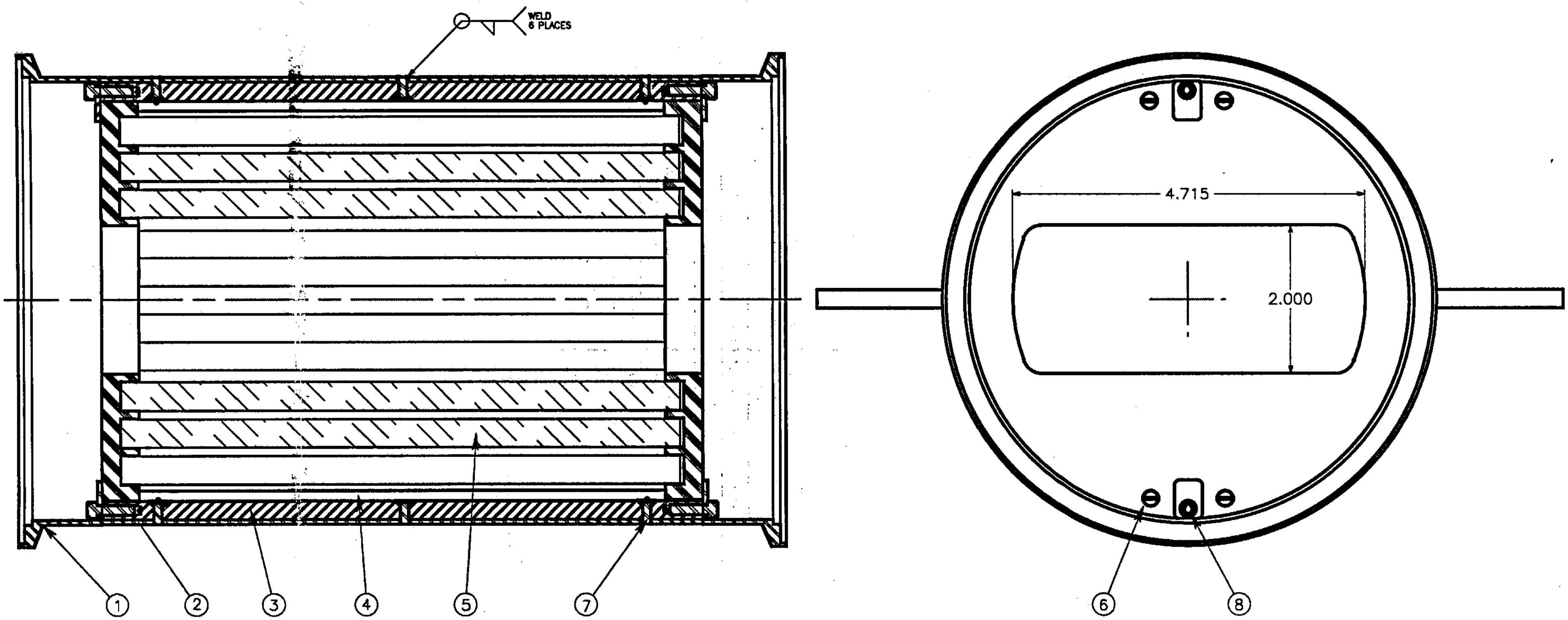
HORIZ AND VERTICAL

SCHOTTKY?



5" DIA. S.S PIPE

I.D. = 4.875



NOTES:

1) ALL ASSEMBLY AND HANDING IS TO COMFORM TO STANDARD HIGH VACUUM PRACTICE.

2) ALL VACUUM WELDS TO BE MINIMUM PENETRATION, USING A MINIMUM OF FILLER ROD, ONLY AS NEEDED TO ASSURE LEAK TIGHTNESS.

3) ASSEMBLY TO BE VACUUM TIGHT. NO LEAK SHALL BE DETECTABLE ON THE MOST SENSITVE SCALE OF A HELIUM MASS SPECTROMETER LEAK DETECTOR WITH A MINIMUM SENSITIVITY OF 2x10E-10 ATM-CC/SEC FOR HELIUM.

4) ASSEMBLY: TO BE ASSEMBLED, CLEANED, AND PACKAGED SO AS TO ASSURE NO CONTAMINATION FROM FOREIGN MATERIALS, METAL CHIPS OR OTHER CONTAMINATES. CLEANING PROCEDURE TO BE APPROVED BY FERMILAB.

ABSORBER FOR
RESISTIVE WALL MONITOR

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.
8		6-32NC ALLEN HD. 1/2" SCREW	4
7		4-40NC FLAT HD. 3/8" SCREW	6
6		4-40NC BIND HD. 1/2" SCREW	8
5	RMX375-7.500	FERRITE ROD (MAGNETICS)	74
4		SPACER ROD	4
3		ALIGNMENT GUIDE	2
2		REXOLITE SUPPORT	2
1		HOUSING ASSEMBLY	1

PARTS LIST

ORIGINATOR	B. FELLENZ	10-6-97
DRAWN	B. FELLENZ	10-6-97
CHECKED		
APPROVED		

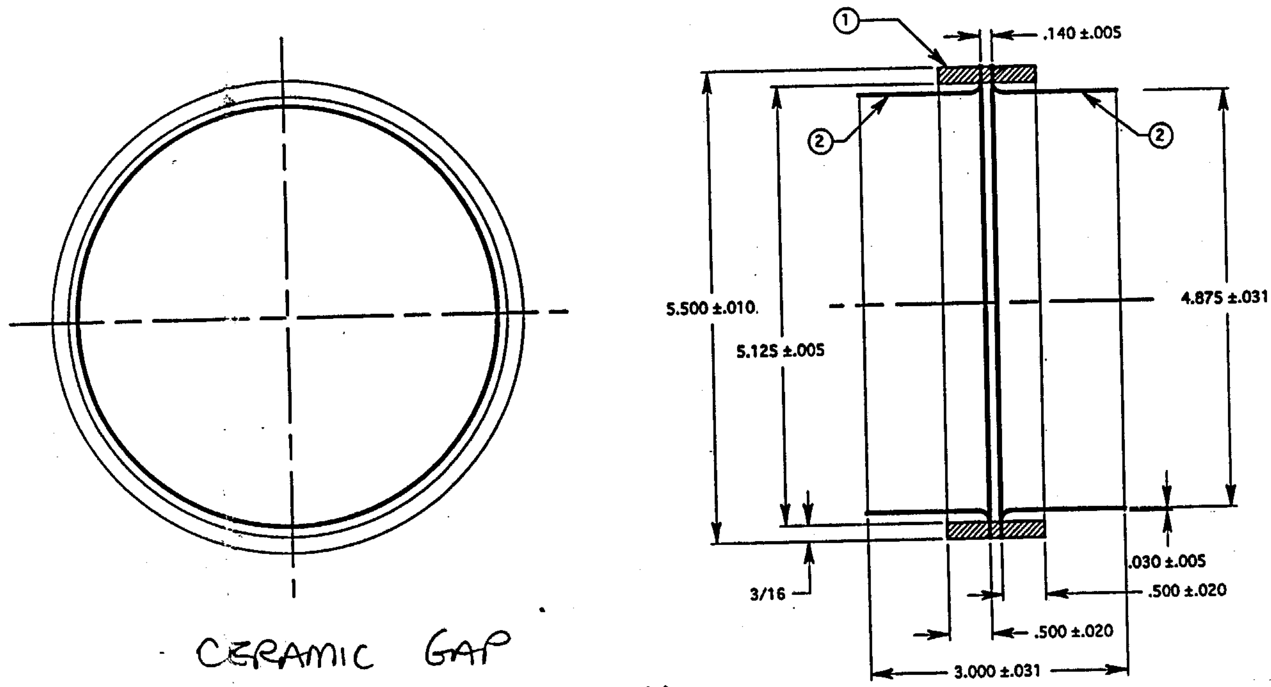
USED ON

MATERIAL

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

MAIN INJECTOR MICROWAVE ABSORBER ASSEMBLY

SCALE: FULL



CERAMIC GAP
FOR RESISTIVE WALL MONITOR

$\varepsilon_r \simeq 10$

$Z = \frac{377}{\sqrt{10}} = 120$ OHMS PER SQ

DIAMETER $= \frac{5.5 + 5.125}{2}$

GAP LENGTH $=$ CIRC $\frac{\text{GAP IMPEDANCE}}{\text{OHMS / SQUARE}}$

$= .14''$ FOR 1Ω GAP

NOTES:
1. THICKNESS OF CERAMIC IS PRIOR TO METALLIZING: ALL FACES TO BE FLAT AND PARALLEL TO WITHIN .005 INCH MAX.
2. METALLIZE FACES WITH MOLY/MAGANESE AND NICKEL PLATÉ, ALL SURFACES EXCEPT O.D. AND I.D. OF CENTER RING.
3. O.D. OF CENTER RING TO BE POLISHED TO 20-MICROINCHES MAX.
4. KOVAR TO BE BRAZED TO CERAMIC, LEAK TIGHT TO 1X10E-9 CC/SEC AT 1-ATMOSPHERE DIFFERENTIAL PRESSURE. CERTIFICATE OF COMPLIANCE WITH LEAK TEST REQUIREMENTS SHALL BE FURNISHED WITH SHIPMENT.
5. CERAMIC GAP ASSEMBLY SHALL BE FREE OF BURRS, CHIPS, CUTTING OILS AND OTHER CONTAMINATES.

REV.	DESCRIPTION	DRAWN	DATE
		APPD.	DATE

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.
2	KOVAR	METAL	2
1	RW97 OR EQUAL	CERAMIC	3

PARTS LIST

UNLESS OTHERWISE SPECIFIED		
FRACTIONS +/- 1/32 · DECIMALS +/- .005 · ANGLES +/-		
1. BREAK ALL SHARP EDGES 1/64" MAX. 2. DO NOT SCALE DRAWING. 3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD'S.		
MAX. ALL MACHINED SURFACE		
Claris CAD 2.0v3		
ORIGINATOR	B. FELLENZ	11-21-95
DRAWN	B. FELLENZ	11-21-95
CHECKED		
APPROVED		
USED ON	9550-ME-309346	
MATERIAL		

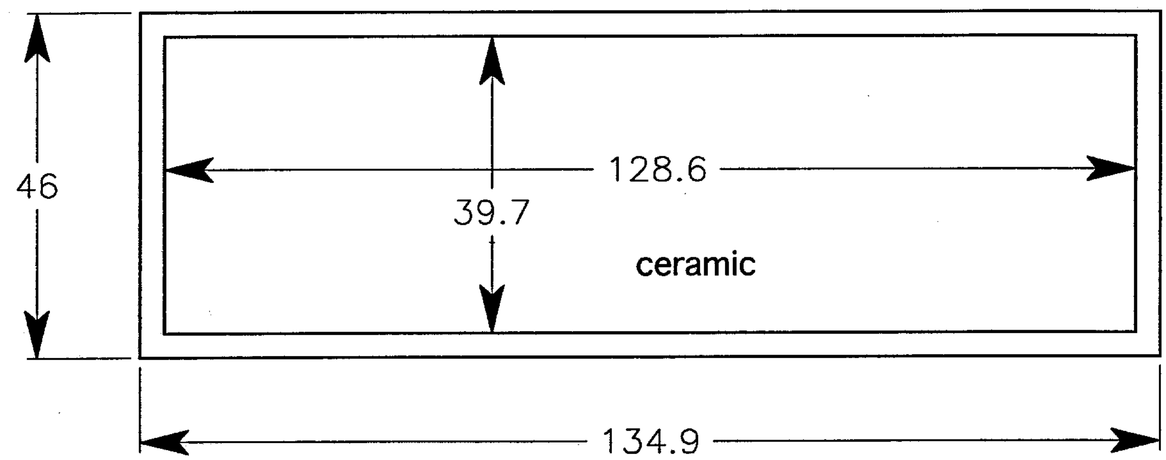
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

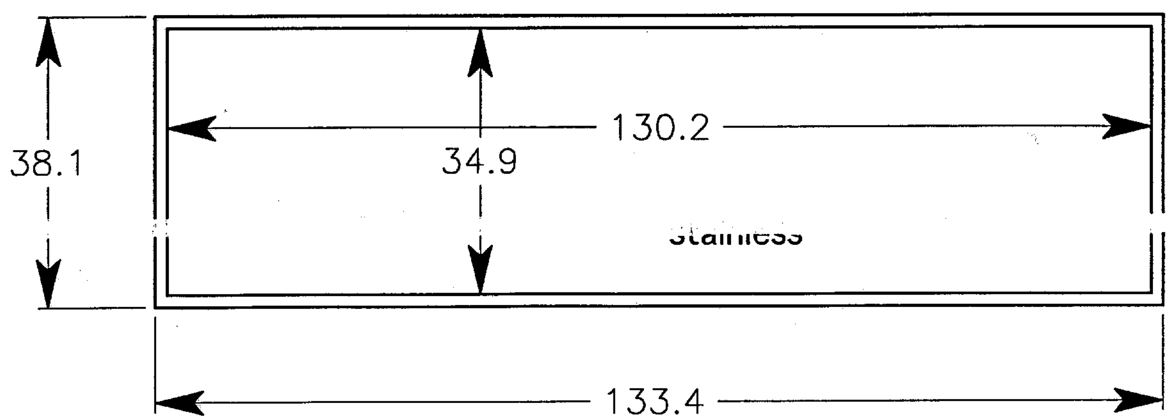
MAIN INJECTOR WALL CURRENT MONITOR
CERAMIC BREAK ASSEMBLY

SCALE	FILMED	DRAWING NUMBER	REV.
1:1		9550-MC-309360	

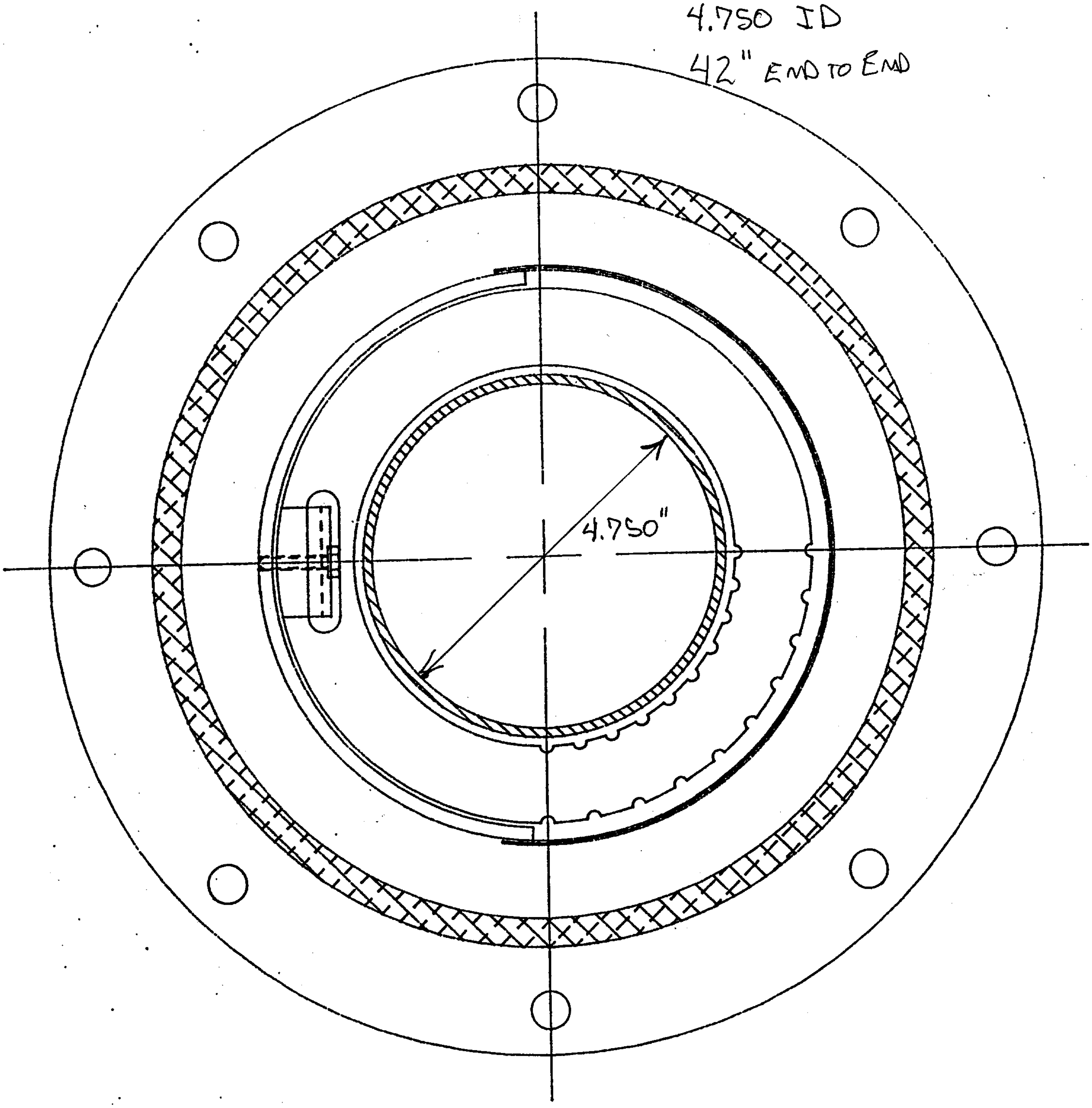
MI Pinger, aproximate dimensions

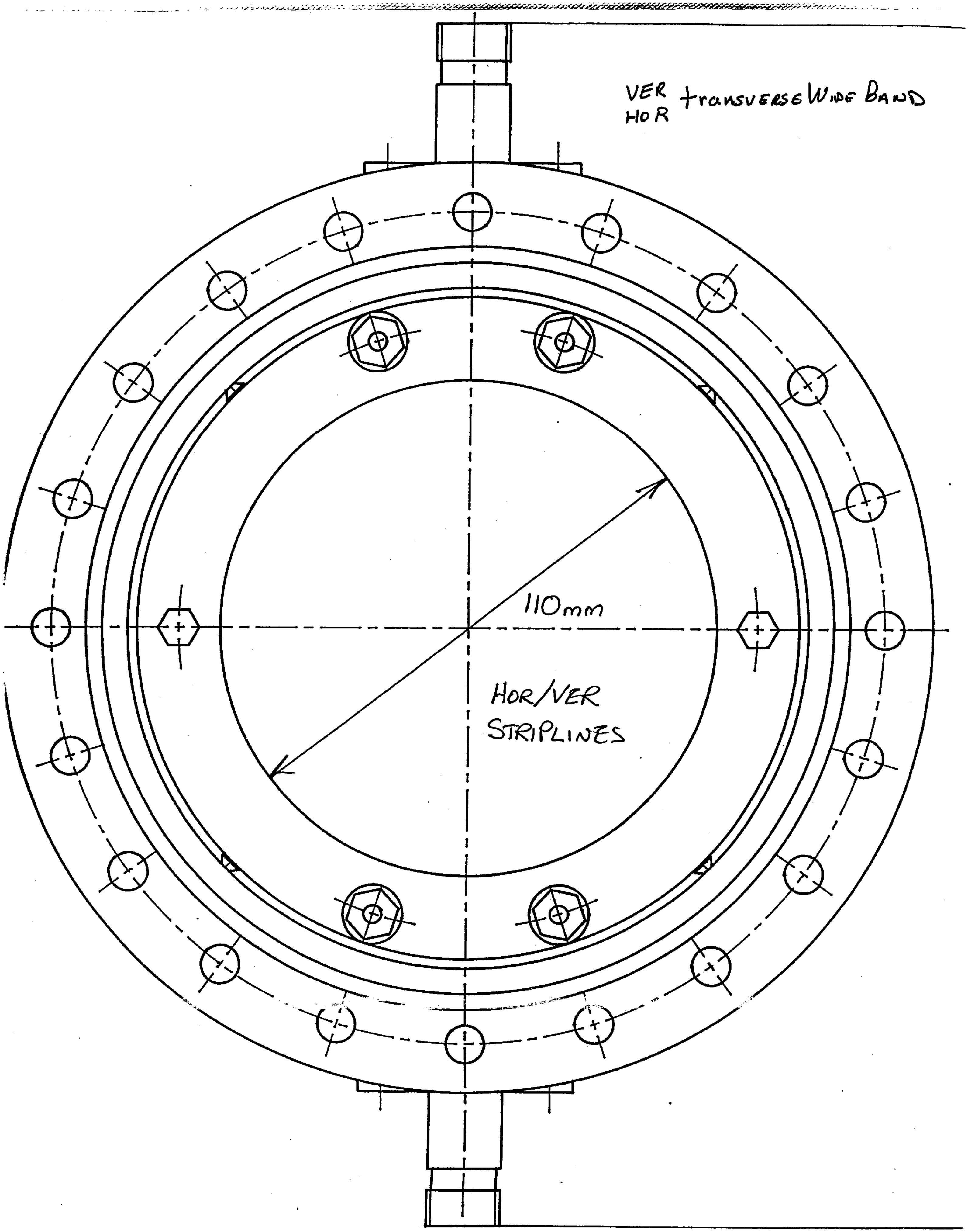
The tubes are rectangular with a slight curvature. The ceramic section is 1.8125 by 5.3125, the SS section is 1.5 by 5.25 (OD Meas +-.062).





MI DCCT
SCALE 1:2
4.750 ID
42" END TO END




VER
HOR
transverse Wide Band
110mm
HOR/VER
STRIPLINES